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OF
ELEMENTARY BOTANY

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LABORATORY MANUAL
OF
ELEMENTARY BOTANY

BY

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SECOND EDITION
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LABORATORY MANUAL OF ELEMENTARY BOTANY

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PREFACE

This laboratory manual in its present edition differs from the previous one in containing some minor changes and additions designed to make it consistent with the new second edition of the author's textbook, "An Introduction to Botany." It consists of 116 independent exercises. They are not all of equal length, but only a few are too long to be completed within a single two-hour laboratory period. Sufficient material has been provided for an average class meeting twice a week for two semesters, but the plan of the manual is such that, where a one-semester course is given, the instructor may readily omit whatever exercises he chooses.

As stated in the author's textbook, the present course is designed to introduce the college student to the science of plant life, presenting such basic facts and principles concerning plants as are essential to an understanding of their structure, functions, and life relations. It attempts, not to cover any phase of the subject in an exhaustive way, but to furnish a foundation upon which more advanced studies may be based.

The directions in the manual have been made as simple and concise as possible, and little descriptive matter has been introduced. An inclusion of numerous statements made in the textbook would be superfluous. Students can readily obtain, before coming to the laboratory, whatever previous knowledge of the subject is necessary. Where such information is included in a laboratory manual, students are inclined to pay scant attention to it, reading carefully only statements telling them what to do. The exercises are designed to direct attention to the most significant features of the material being studied, so that the students' time may be most expeditiously and profitably spent. To this end some questions are asked, especially where questions will stimulate inquiry to a greater extent than descriptive statements. Questions whose answers are perfectly obvious, however, are omitted, and few questions are asked that cannot be answered directly from the material at hand. Questions designed to promote the drawing of general conclusions or to stimulate discussion, for the most part, are not included in the manual. These can be asked to better advantage by the teacher himself in connection with recitations based on lectures or on readings in the textbook.

ARTHUR W. HAUPT.

LOS ANGELES, CALIF.,
May, 1946.

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LABORATORY MANUAL
OF
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GENERAL DIRECTIONS

Supplies.—Before beginning the laboratory work, the student will provide himself with the following materials: (1) A set of dissecting instruments consisting of a scalpel, forceps, pair of dissecting needles, safety-razor blade, dropping pipette, and celluloid ruler. (2) A tripod magnifier. (3) Three microscope slides and a dozen cover glasses; also a piece of soft linen cloth for cleaning them. (4) A loose-leaf notebook cover about 9 by 11 inches in size. (5) A supply of smooth, white, unruled drawing paper; linen ledger is the best. Some ruled paper or a cheaper grade of unruled paper of the same size will be needed for written work. (6) A bottle of black waterproof India ink. (7) A medium hard pencil (2*H*), a penholder, six drawing pens (*Spencerian No.* 1), an ink eraser, and a soft pencil eraser.

Laboratory Work.—At the beginning of the course it is essential to realize the importance of laboratory work and to acquire the proper attitude toward it. Lectures and textbooks provide only secondhand information, and while they are indispensable to the proper study of botany, a real knowledge of the subject will come primarily through individual efforts in the laboratory. Work should not be done in a purely mechanical way, as such a procedure will be without permanent value. The significance of each assignment should be recognized and its bearings on the general subject appreciated. Before an exercise is begun, the directions should be carefully read and then followed explicitly. Do not rely upon others for assistance, but learn to work independently. Success in the course will largely be determined by your ability to see things and to interpret them yourself.

Drawings and Notes.—The object of laboratory work in botany is not to make a set of drawings, but to study plants. Drawings are not an end but a means—a means of representing your own interpretation of the things observed. Inability to represent on paper what one has seen is nearly always an indication of faulty observation, and not a lack of ability to draw. Elaborate drawings are not required and should not be attempted. There are two prime requisites for successful laboratory work in botany: *accuracy* and *neatness*. Every line must stand for a structure. Outlines must be continuous and distinct. In nearly all cases shading is unnecessary and should be avoided. Drawings should be large enough to show necessary details. A common tendency of beginners is to make drawings too small. In drawing to scale, use the celluloid ruler. First draw with a pencil, and as soon as possible go over the lines with India ink. Do not make crude sketches in the laboratory and finish them outside. All work should be done in the laboratory.

Notes should be taken on features not brought out by the drawings, and must always be written up in ink and in the form of complete sentences. Notes should be made when studying the material, not afterward. Answers to all questions should be written out. Under no circumstances should drawings or statements be copied from reference books or from other members of the class. In describing experiments complete facts should be given as to the object of the experiment, the materials used, the procedure followed, the results obtained, and the conclusions drawn.

Headings and Labels.—Each exercise is to be headed to correspond with the topics in this manual. The name of each individual drawing should appear below it, as in a textbook. The details of the drawing, those parts to which attention has been directed (usually printed in italics in the manual), should be neatly labeled by means of horizontal dotted lines to the right of the drawing. Always indicate the scale, as ×½, ×1, ×2, ×250, etc.

Throughout the following exercises, *m* signifies that the object is to be studied under the tripod magnifier or under a binocular dissecting microscope; *lp* and *hp* refer to the low and high powers of the compound microscope.

SEED PLANT BODY

Exercise 1

BEAN SEEDLING

Examine an advanced seedling of scarlet runner bean and observe that it is composed of a *root system* growing down into the soil and a *shoot system* growing up into the air. Carefully wash away the soil from the root system and note that it consists of a *primary root* and a number of *secondary roots* arising as branches from it. Is there any regularity in their arrangement? The shoot system includes the stem and leaves. The first pair of leaves, called *cotyledons*, are inside the dried seed coat. The other leaves are known as *foliage leaves.* Examine the cotyledons and find out how they differ from the foliage leaves. The food which they contain is rapidly being absorbed by the growing seedling. What finally happens to the cotyledons?

Each foliage leaf is composed of a flat *blade* and a slender leafstalk or *petiole.* The blade may be in one piece or may be divided into separate *leaflets.* Compare the lowermost pair of foliage leaves with the upper (younger) ones and note all of the ways in which they differ. What position do the leaves assume with reference to the light? Of what significance is this? How do you explain the presence of green color in the stem and leaves and its absence in the roots? What are the main functions of the root, stem, and leaf?

Find the *terminal bud* at the apex of the stem. This contains rudiments of leaves that will subsequently unfold and enlarge. Can you find a minute *lateral bud* at the base of each leafstalk? A lateral bud originates in the *axil* of the leaf. Is this above or below the point of attachment between the leafstalk and the stem? Into what do these buds develop?

Make a drawing of the bean seedling, one-half natural size.

PROTOPLASM AND THE CELL

Exercise 2

THE COMPOUND MICROSCOPE

In using the compound microscope it is essential that you thoroughly understand its mechanism. Faulty manipulation will not only hinder your work, but may result in costly damage. Remove the instrument from its case, but *do nothing with it* until you have carefully studied the following directions.

Notice first the *stage* upon which objects are placed for examination. Only transparent objects are examined with the compound microscope. Light is reflected up through the object to be examined by the *mirror*, located beneath the stage. Note that it has a flat and a concave side. See that the *mirror bar* is vertical; it must always be kept in this position. The *diaphragm* is a device for regulating the illumination of the object to be examined. It may be found on the under side of the stage. Determine how it operates.

Observe the two sets of lenses. The lens at the top of the tube is called the *ocular* or *eyepiece*, and the lower ones the *objectives*. Do not change the position of the objectives at this time, but note that either one may be put in a straight line with the tube. The shorter objective is the *low-power* objective; the longer one is the *high-power* objective. It is very important that you learn to distinguish these before using the microscope, and to know that the high-power objective is always used *after* the object has been examined under the low power.

Study now the focusing mechanisms. One is the *coarse adjustment*, the other the *fine adjustment*. Note the action of the coarse adjustment, but in turning it be extremely careful not to run the tube so far down that the objective touches the stage. Observe that the tube is *raised* as you turn the coarse adjustment *toward* you. Remember this fact. The fine adjustment should never be turned more than one or two complete revolutions in either direction. The object is first brought into focus by means of the coarse adjustment. Focusing for details is then done with the fine adjustment.

Microscopic objects are mounted on thin glass *slides*, and are always mounted in some transparent medium. A small thin glass, the *cover glass*, is always placed over the object. Both slide and cover glass must be very clean. Some of the objects that you will study will be in the form of *permanent mounts* (or *prepared slides*). Others will be mounted by you as *temporary mounts*. Such a mount you will now make.

With your forceps carefully remove a single leaf from a living moss plant, and place it in the center of a clean slide. Add a drop of water with your pipette, and place a clean cover glass over the leaf. Be careful not to have the upper side of the cover glass wet. Now place the mount on the stage of the microscope, having the object on the slide exactly in the center of the opening in the stage. See that the low-power objective is in a straight line with the tube of the microscope. Using the coarse adjustment, move the tube so that the objective is about 6 mm. (¼ inch) above the slide. Now look through the ocular and adjust the flat side of the mirror until you see a clear field of bright light. As you look through the microscope, slowly turn the coarse adjustment *toward* you until the object comes into view. If you have trouble, ask for assistance. Move the slide around and examine all parts of the leaf, practicing until you can do this without losing sight of the object.

Before proceeding farther, move the slide so that a portion of the leaf is directly in the center of the field of vision. *Without disturbing the focus*, swing the high-power objective into position. Unless your instrument is an old model, you should be able to do this without having the objective come in contact with the slide. (In using an old microscope, the tube must be raised slightly before the high-power objective can be swung into position.) Now use the fine adjustment to focus for details, never turning it more than one or two revolutions in either direction. This is important, as contact of the objective with the slide will break the cover glass, thus ruining a permanent preparation, and may scratch the expensive lens. Most microscope damage is incurred through a failure to use the high-power objective with extreme care. In focusing with the fine adjustment, observe that the object has depth as well as length and width. No objects are truly flat. It is only by realizing this fact that you will be able to study with the microscope intelligently. As you examine various objects, always study them in all three dimensions.

In order to obtain satisfactory results from studies with the compound microscope, and to avoid breakage, learn the following rules:

1. Never focus down on an object unless it is so nearly in focus that you can see its outlines.
2. Never use the high-power objective before first bringing the object into focus and centering it under the low power.
3. Use the coarse adjustment only in combination with the low-power objective, and the fine adjustment only with the high-power objective.
4. Do not turn the fine adjustment more than one or two complete revolutions in either direction.
5. Never allow either objective to come in contact with the stage or with a slide.
6. Never use anything but lens paper for cleaning lenses.
7. Do not unscrew or remove any parts of the instrument.
8. Whenever you are not getting good results with your microscope, call for assistance.

Exercise 3

LIVING PLANT CELLS

Prepare temporary mounts and study (*hp*) living cells from hairs on a squash petiole, from epidermis stripped from an inner scale of an onion bulb, from a young leaf of waterweed (*Elodea*), or from other favorable material. Study the form and arrangement of the cells and their relative size. As you focus up and down with the fine adjustment, note that each cell has thickness as well as length and width. Distinguish carefully between the nonliving *cell wall* and the *protoplast*, or mass of living matter, which it encloses. If green bodies (*chloroplasts*) are present, observe their form and distribution; their color is due to a pigment called *chlorophyll.* Observe the strands of *cytoplasm* surrounding clear spaces called *vacuoles.* In some cells there is one large central vacuole around which the cytoplasm occurs as a thin layer. If the cytoplasm shows streaming movements, study carefully. The *nucleus* may or may not be visible in the living cell, but often can be rendered so by placing the tissue in a weak iodine solution for a few minutes. Note the size and form of the nucleus and its position within the cell.

Draw a small group of cells of each kind studied, indicating clearly all of the features noted. Represent protoplasm by stippling.

Exercise 4

ROOT-TIP CELLS

Examine a prepared slide showing a longitudinal section through a root tip. These cells have been killed, sectioned, and stained by special methods so as to show features not readily seen in living cells. Study (*hp*) the cells which lie just back of the rootcap, noting the *cell wall*, the dense *cytoplasm*, and the relatively large central *nucleus.* Which is stained more deeply, the nucleus or the cytoplasm?

Observe that the cytoplasm contains many small *vacuoles* with innumerable minute granules between them. Study the structure of the nucleus, noting the *nuclear membrane,* the granules of *chromatin,* and the dense *nucleoli.* Now study cells a little farther back from the rootcap, and observe their greater length. How does the character of the cytoplasm compare with that of the cells previously studied? Has the nucleus increased in size?

Draw several cells both from the younger and older parts of the root tip, indicating very accurately the structure of the nucleus and of the cytoplasm.

Exercise 5

MITOTIC CELL DIVISION

Prepared slides of root tips (or of other favorable material) showing various stages in vegetative mitosis will be found under the demonstration microscopes. Study each one very carefully before drawing. Because of the high magnification, it will be necessary to focus slightly with the fine adjustment before drawing. This is important, for without focusing you will be unable to see all the details.

In the early stages of mitosis, constituting the *prophase,* note the presence of numerous deeply stained, rod-shaped bodies formed by the consolidation of the chromatin of the resting nucleus. These are *chromosomes.* How are they arranged? Is the nuclear membrane still present and can the nucleolus be identified?

In a later stage, the *metaphase,* a bipolar spindle formed of very delicate fibers can be seen, the chromosomes being arranged at the equator. Because you are looking at the spindle from the side, the chromosomes seem crowded together, but several of the individual ones may usually be seen by careful focusing. Note that each chromosome is longitudinally split in two.

After the split chromosomes have become arranged at the equator of the spindle, the halves of each one move toward opposite poles. Observe the stage showing the two groups of separating chromosomes, the *anaphase*, and note that most of them are U-shaped. After the two groups of chromosomes have reached the poles, a cell wall forms between them on the spindle fibers, thus cutting the old cell in half. Observe such a *telophase*, noting the condition of the chromosomes.

Make a series of very accurate drawings showing all the stages in mitosis which you have studied. Also draw a single resting cell.

Exercise 6

SIMPLE PERMANENT TISSUES

The growing regions of a plant are composed of embryonic tissue. This has already been studied in Exercise 4. What are the characteristics of embryonic cells? Permanent tissues, which are derived from embryonic tissue, are more or less differentiated in structure and specialized in function. Simple tissues consist of only one kind of cells. There are five principal kinds of simple permanent tissues.

Epidermis.—Study (*lp*) cross sections of a petiole or of a young herbaceous stem. The outermost layer of cells constitutes the epidermis. Note their uniform size and form and their compact arrangement. Observe (*hp*) the waxy substance (*cutin*) on their outer cell walls. What is its function? Do you find chloroplasts in the epidermal cells? Do you find cytoplasm and a nucleus?

Draw several epidermal cells.

Parenchyma.—Using the same section, observe (*lp*) the large, thin-walled, relatively undifferentiated cells in the center. Are they compact or loosely arranged? Examine (*hp*) more closely and determine whether cytoplasm, a nucleus, and chloroplasts are present. Can you find parenchyma in other parts of the section?

Draw a group of parenchymatous cells.

Collenchyma.—Collenchyma is a strengthening tissue frequently present in the outer portion of herbaceous and young woody stems and in the petioles of leaves. Examine (*hp*) collenchyma in a cross section of a beet petiole or other material and observe that the cell walls are greatly thickened at the corners. Are the cells living?

Draw a group of collenchymatous cells.

Sclerenchyma.—This is also a strengthening tissue, but it consists of empty cells with heavily and uniformly thickened walls. *Fibers* are long slender cells with pointed ends. *Stone cells* are short. Study (*lp*) fibers in cross and longitudinal sections of a stem, observing their compact arrangement in distinct groups. Note (*hp*) the character of the cell walls. These are generally impregnated with *lignin*, a substance that gives them great strength. Study (*hp*) stone cells in the outer part of a cross section of a stem or in the flesh of a pear. Observe the cell cavity and the minute radiating canals extending through the thick cell wall.

Draw several fibers and stone cells.

Cork.—In a cross section through an old geranium stem or the outer part of a potato tuber, study (*hp*) the layers of cork cells. What is their form and arrangement? Do they have protoplasmic contents? What is the function of cork?

Draw a group of cork cells.

Exercise 7

COMPLEX PERMANENT TISSUES

Complex tissues are composed of two or more different kinds of cells. There are two main kinds of complex permanent tissues, both of which are conductive in function.

Xylem.—In a cross section of a petiole or of a young herbaceous stem with distinct vascular bundles, identify (*lp*) the thick-walled woody tissue or xylem that forms part of each vascular bundle. Study (*hp*) the form and arrangement of the cells and the character of their cell walls. Are any of the cells living? Can you recognize more than one distinct kind of xylem cell? In a longitudinal section these cells are seen to be greatly elongated and to have lignin deposited on their walls in characteristic patterns.

Phloem.—Examine (*hp*) the thin-walled phloem cells that lie next to the xylem in each vascular bundle. Are they living? The principal elements of phloem are sieve tubes, elongated cells with perforated walls. If xylem and phloem elements are to be studied in detail, see Exercise 26.

Draw a small vascular bundle, showing its component xylem and phloem cells.

SOME CELLULAR PROCESSES

Exercise 8

IMBIBITION

Obtain a piece of dried gelatin about 2 or 3 cm. square and measure its exact dimensions. Then place it in water for two hours and measure again. Allow the gelatin to remain in water overnight and then measure. Calculate the number of times the piece of gelatin has increased in volume. How do you account for this increase? What part does imbibition play in the absorption of water by cell walls and protoplasm?

Exercise 9

DIFFUSION

Place a crystal of some colored salt, such as copper sulphate or potassium bichromate, in a test tube of water with a piece of white paper behind it, and do not disturb for several days. Minute particles of the salt pass out into the water to mingle with the water particles. At the end of two hours measure the height reached by the salt particles, and measure again in a day or two. In terms of concentration of salt particles per unit volume of water, in what direction has the diffusion of the salt taken place?

Exercise 10

OSMOSIS

Fill a thistle tube with a strong solution of cane sugar or of sodium chloride, and firmly tie a piece of parchment (or some other suitable membrane) over the large end. Place in a jar of distilled water so that the membrane is well below the surface, and support with a ring stand and clamp.

Attach a long piece of glass tubing to the upper end of the thistle tube. Note the level of the solution and measure any change after 24 and 48 hours. The membrane is freely permeable to the water particles, but almost completely checks the free diffusion of the salt or sugar particles through it. In terms of concentration of the dissolved substance, in which direction has the water moved? What force is supporting the liquid in the tube? What determines the level it finally reaches?

Make a drawing of the apparatus and fully explain the results of the experiment.

Exercise 11

PLASMOLYSIS

Place a young leaf of waterweed (*Elodea*), epidermis stripped from a leaf of wandering Jew (*Zebrina*), or other favorable material in a weak solution[1] of sodium chloride for 2 or 3 minutes, and then examine (*hp*), using a drop of the salt solution as a mounting medium. Observe and record by means of three or four drawings successive changes in the appearance of the cells. Then transfer the material to pure water for a few minutes and draw again. In the plasmolyzed cells, what lies between the cell wall and the plasma membrane? Does the salt solution penetrate the protoplast? If left too long in the salt solution, why does the cell fail to regain its turgidity when put back into pure water? What maintains the turgidity of a normal living cell? Why does a leaf wilt when removed from a plant and exposed to the air? Fully explain the results of the experiment as recorded by the drawings you have made.

Cut two slices about 5 mm. thick from a potato. Put one slice in a dish of water and the other in a strong solution of sodium chloride. After about half an hour note any difference between the two slices in size and stiffness. How do you explain? How does osmosis maintain turgidity of plant tissues?

---

[1] Not over 5 per cent strength.

Exercise 12

DIFFERENTIAL PERMEABILITY OF LIVING MEMBRANES

Cut two slices about 5 mm. thick from a beet and wash them in distilled water. Place each slice in a separate dish and cover with distilled water. Heat one of them for one-half hour at 70°C. After 24 hours observe the color[1] of the water in each dish. Then test both liquids for cane sugar (see Exercise 43). What was the effect of heating upon the living cells of the root? What can you say regarding the permeability of the living plasma membrane for sugar that is inside the cell? Fully explain the results obtained in this experiment.

---

[1] The color of the beet is due to the presence of a red pigment dissolved in the cell sap.

THE ROOT

Exercise 13

ROOT SYSTEMS

Compare a plant having a *taproot system* with one having a *fibrous-root system.* The former is dominated by a single main root, while the latter consists of a number of slender roots all equally prominent. The taproot itself is an enlarged primary root, while its slender branches are secondary roots. Is there any regularity to the way in which roots branch? Split open a carrot and determine whether the fibrous secondary roots originate in the central woody portion or in the outer softer portion. Carrots and other fleshy roots contain a great deal of stored food. Roots that arise directly from a stem are said to be *adventitious.* Examine adventitious roots arising from stem cuttings, from a bulb placed in water, from a stem of English ivy, etc.

Draw all the root systems studied. Make a drawing to show the origin of branch roots in the carrot.

Exercise 14

ROOT TIP

Prepare a temporary mount of a grass seedling[1] which has been growing in water and study (*lp*). Identify the following regions: (1) The *rootcap,* a protective sheath fitting over the end of the rootlet. (2) The dense, yellowish *embryonic region,* of very limited extent, lying just behind the rootcap. (3) The more extensive *region of elongation.* (4) The *region of maturation,* easily recognized by the presence of numerous *root hairs.* In the embryonic

[1] Seeds of red top (*Agrostis alba*) placed in water will furnish excellent material after 5 or 6 days.

region cell division is most active; in the region of elongation the newly formed cells increase in length; while in the region of maturation cell differentiation is most active. Note carefully the origin, distribution, and varying length of the root hairs. Carefully examine (*hp*) one of the younger root hairs, noting its connection with the root. Observe the thin layer of cytoplasm around a large central vacuole. Where is the nucleus?

Make a drawing of the rootlet showing its four regions. Also make an enlarged view of a single root hair.

Study (*lp*) a prepared slide showing a median longitudinal section through a root tip. Identify the root cap, embryonic region, and region of elongation. Compare (*hp*) the relative size of the cells in the embryonic and elongating regions, noting especially the enlargement of vacuoles in successively older cells. Does the nucleus increase in size? Can you find evidence of cellular differentiation?

Make an outline drawing of the entire root tip without showing cells. Then draw, in detail, a few cells from each region.

Exercise 15

GROWING REGION OF ROOT

Obtain some seedlings of scarlet runner or of Windsor bean in an early stage of germination. Select one with a straight primary root about 25 mm. (1 inch) long. Make a row of equidistant dots with India ink about 2 mm. apart along the entire length of the root and insert it into the neck of a thistle tube, being careful not to rub off the ink. Loosely pack some moist absorbent cotton in the bulb of the thistle tube and stand its lower end in a bottle partly filled with water. As growth proceeds, note which dots become separated and which become farthest apart. What does this experiment prove in regard to the region of growth?

Make drawings to show the results of your experiment.

Exercise 16

MATURE ROOT

Examine (*lp*) a prepared slide showing cross sections of a mature buttercup root and observe the central *stele* surrounded by the more extensive *cortex*. The latter, bounded externally by a single-layered *epidermis*, is composed of undifferentiated tissue called *parenchyma*. Does it contain intercellular spaces? The innermost layer of the cortex, called the *endodermis*, consists of small cells most of which are thick walled. Do you find (*hp*) any thin-walled cells in the endodermis? If so, note carefully their distribution. The *pericycle*, or outermost portion of the stele, includes the layer of cells that lies just inside the endodermis. Lying within the stele are two kinds of conducting tissues: *xylem* and *phloem*. The xylem, or woody tissue, is thick walled and arranged in the form of a star, while the thin-walled phloem occurs in strands between its rays. Distinguish carefully (*hp*) between the xylem and phloem.

Make a diagram of the cross section studied, indicating the relation of the principal tissues to one another. Then make a detailed drawing of the stele on a much larger scale.

THE STEM

Exercise 17

LEAF ARRANGEMENT

A typical shoot consists of a stem bearing leaves with either buds or developing branches in their axils. Examine such a shoot and identify its main parts. The leaves arise from the stem at definite places, called *nodes*, which are separated by *internodes*. Compare the length of the internodes on the younger and older parts of the stem. How many leaves are borne at each node in the plant you are studying? Does each leaf consist of a *blade* and a *petiole* (leafstalk), or is the latter absent? Is the blade simple or divided into separate leaflets? Is there a pair of small appendages, called *stipules*, at the base of the leaf? Where do the buds originate with reference to the leaves? In addition to the *lateral buds*, which give rise to branches, is there also a *terminal bud* by means of which the main stem increases in length?

Study other shoots with a leaf arrangement different from that of the shoot already examined. The arrangement is *alternate* if but one leaf occurs at a node, *opposite* if two leaves are present, and *whorled* if there are three or more. What plan is seen whereby one leaf does not stand directly over another? Of what advantage is this to the plant?

Make a semidiagrammatic drawing of each of the kinds of shoots studied.

Exercise 18

BUDS AND BRANCHES

Compare the bud arrangement on winter twigs of willow, elm, sycamore, box elder, ash, catalpa, etc. In which do you find a *terminal bud* as well as *lateral buds?* Are the buds provided with *bud scales?* What is their function? Note the presence of a *leaf scar* below each lateral bud. What does this represent? The leaf scars mark the position of the *nodes.* These are separated by *internodes.* Are all the internodes of equal length? In each twig determine whether the arrangement of the lateral buds is *alternate,* with one at a node, *opposite,* with two, or *whorled,* with three or more. Examine (*m*) the blister-like dots or lines on the bark. These are *lenticels,* openings through which air enters the stem.

Draw any three winter twigs showing alternate, opposite, and whorled arrangement of buds.

Cut a large vegetative bud lengthwise through the center and examine (*m*). Distinguish between the stem tip and the rudimentary leaves. Where are the youngest leaves? Do you find any evidence of the formation of lateral buds in the leaf axils? Look at a shoot with "opening" buds, preferably in several stages of growth. Into what does a vegetative bud develop?

Make a diagram of the structure of a bud and of its development into a shoot.

Exercise 19

TWINING STEMS

Climbing plants, or *vines,* grow upright by becoming attached to a support. They may climb by twining, by producing tendrils, or by means of anchoring roots. Observe any available twining stems, such as those of the hop, honeysuckle, bean, and morning-glory, and note whether the direction of twining, as seen from above, is clockwise or counterclockwise. If living plants are available, note the changing position of the stem tip over a period of several hours. To what is this movement due?

Make a drawing of a twining stem.

Exercise 20

FOOD-MANUFACTURING STEMS

In plants whose leaves are reduced to scales or spines, photosynthesis is carried on by the stem. Observe the green fleshy stem of a cactus with its numerous spines and note any adaptation for securing increased exposure of surface to the light. The flattened branches of the common "smilax" are called *cladophylls*. Although leaf-like in appearance, what evidence can you find as to their real nature?

Draw the food-manufacturing stems studied.

Exercise 21

STEM THORNS AND STEM TENDRILS

Observe plants with stem tendrils, such as the passion-flower, grape, Virginia creeper, Japanese ivy, squash, cucumber, etc. In which are adhesive disks present? Does the tendril coil after coming in contact with the support? Does the position of the tendrils with reference to the leaves present any evidence for regarding them as specialized stems? Explain.

Draw a shoot bearing stem tendrils.

Stem thorns may be seen in the honey locust, hawthorn, wild crab apple, Osage orange, and many other plants. Note the place of origin of the thorns with reference to the leaves or leaf scars. What does this indicate regarding their nature? Are the thorns simple or branched? Do any of them bear leaves or buds?

Draw a stem whose branches are modified as thorns.

Exercise 22

UNDERGROUND STEMS

A *rhizome* is generally an elongated stem growing horizontally in the soil. Study several kinds, as seen in Solomon'sseal, May apple, bloodroot, iris, quack grass, etc. Which of the rhizomes studied gives rise to an erect leafy stem? In which is considerable food stored? Which of the following structural features do you find present: nodes and internodes, adventitious roots, leaves or leaf scars, scales or scale scars, a terminal bud, lateral buds, lenticels? Why are rhizomes efficient organs of vegetative propagation?

A *tuber* is a short thickened portion of a rhizome specialized for food storage. Examine a potato tuber and enumerate all the ways in which it resembles a rhizome. Which end was attached to the parent plant? What are the "eyes"? Do they exhibit a definite arrangement? A *bulb* is really an enlarged underground bud. Cut an onion bulb in half lengthwise and distinguish between the stem portion and the fleshy leaf bases. Where is most of the food stored? Compare the structure of a bulb with that of a *corm*, as seen in the cyclamen, Jack-in-the-pulpit, crocus, or gladiolus. Where in a corm is the food stored? Are scales or leaf bases present?

Draw each of the different types of underground stems studied.

Exercise 23

STEM TIP

Examine (*lp*) a prepared slide showing a median longitudinal section through a stem tip and note the cone-shaped *apical meristem* and the *leaf primordia* arising below it. Where are the youngest primordia? Do you find any evidence of the formation of lateral buds in the leaf axils? Study more closely (*hp*) the stem tip. How extensive is the embryonic region? Do you find any evidence of cell elongation or of cell differentiation?

Make an outline drawing of the section, omitting cells. Then draw, in detail and on a larger scale, the apical meristem and the two leaf primordia closest to it.

Exercise 24

YOUNG WOODY STEM

Study (*lp*) a prepared slide showing a cross section of the stem of a typical woody dicotyledon in its first year of growth. Distinguish between the central *pith*, the surrounding *vascular cylinder*, and the peripheral *cortex*. The pith and the vascular cylinder together constitute the stele. Of what kind of tissue is the pith composed? The greater portion of the vascular cylinder consists of *xylem* (wood), while just outside of the xylem is a narrow zone of *phloem*. Between the xylem and phloem is a layer of actively dividing cells called the *cambium*. Observe the radiating *vascular rays* traversing the vascular cylinder.

The cortex is bounded externally by a single-layered *epidermis*. Note (*hp*) the waxy substance forming a *cuticle* on its outer surface. Of what kind of tissue is the cortex mainly composed? Observe (*hp*) that the cells of the xylem are thick walled and mostly devoid of protoplasm. Are they approximately uniform in size or not? Identify the cambium and notice that it gives rise to secondary phloem toward the outside and secondary xylem toward the center. How are the cells cut off from the cambium arranged? Can you identify the *primary xylem*, consisting of small groups of cells adjacent to the pith? In the secondary phloem, can you distinguish between the larger *sieve tubes* and the smaller *companion cells?* Are any thick-walled cells present in the phloem? If so, they are fibers. The cells of the *primary phloem*, lying just beyond the secondary phloem, are more or less crushed. Why? The region lying between the phloem and the cortex is called the *pericycle*. Of what kind of tissue is it mainly composed? *Sclerenchyma* in the form of *fibers* may occur in the pericycle or in the cortex. Fibers may be recognized as groups of thick-walled cells sometimes forming a continuous cylinder. Look for *stone cells*, another kind of sclerenchyma, in the pericycle or in the cortex. How do they differ from fibers?

Make a diagram of the stem studied, showing the relative extent of its main tissues and their relation to one another. Draw in detail a portion of the cambium with its contiguous xylem and phloem. Also draw groups of individual fibers and stone cells, if present.

Exercise 25

OLDER WOODY STEM

Examine (*lp*) a cross section of an older woody stem of the same species as that studied in the last exercise. What changes, if any, have taken place in the pith, vascular cylinder, and cortex? Count the successive layers of wood and in so doing determine the age of the stem. Each season's accumulation of xylem is known as an *annual ring.* Examine (*hp*) the boundary between two successive annual rings, where the summer wood of one season's growth comes in contact with the spring wood of the next. How do the spring and summer wood differ? Do all the vascular rays extend from the pith to the cortex? Observe the formation of *cork* outside of the cortex. It has been formed by the *cork cambium.* Is cork tissue living or dead? What is its function? Is the epidermis still present? Look for *lenticels,* openings in the corky layer.

Make a diagram of the older stem on the same scale as that of the younger stem previously drawn. Also make a detailed drawing showing contact between the wood of two successive growing seasons.

Exercise 26

CONDUCTING TISSUES

Study (*lp*) longitudinal sections of some herbaceous stem and identify *spiral, annular,* and *pitted vessels.* Examine each (*hp*) and determine its distinctive features. In the pitted vessels, find places where the end walls have broken down. Of what significance is this? Study *sieve tubes,* the large conducting elements of the phloem, noting the perforations in their end walls.

Draw each kind of conducting element studied.

Exercise 27

HERBACEOUS STEM

Study (*lp*) a cross section of the stem of a herbaceous dicotyledon having separate *vascular bundles.* Observe that the vascular cylinder is broken up by wide extensions of the pith called *pith rays.* Does the cambium occur between the bundles as well as within the bundles themselves? Do you find vascular rays within the bundles? Identify (*hp*) all the tissues seen.

Make a diagram of the stem studied. Also draw a single vascular bundle in detail.

Exercise 28

STEM OF A MONOCOTYLEDON

Examine (*lp*) a cross section of a young corn stem and note that the conducting tissues are confined to separate *vascular bundles.* Do these have a definite arrangement? In what part of the stem are the bundles closest together? Look (*hp*) at a single bundle and distinguish between the xylem and the phloem. Is there evidence of the presence of a cambium? Find the two large *pitted vessels* with one or two *annular* or *spiral vessels* lying between them. Note the large air space. Observe the thick-walled fibers surrounding the bundle. The phloem is very distinct and consists of *sieve tubes* and *companion cells,* the latter being small. What is the position of the phloem with reference to the xylem?

Make a diagram of a cross section of a corn stem, showing the approximate number, relative size, and distribution of the vascular bundles. Also make a detailed drawing of a single bundle.

Exercise 29

ASCENT OF WATER

Cut off a shoot from a vigorous herbaceous plant[1] and immediately immerse the lower end in water colored with a small amount of eosin or of some other dye. Note the rise of the solution in the shoot until it has reached the ends of the veins. Cut thin cross sections of the stem and note (*lp*) the presence of the stain in the vascular system. Through which cells does the water ascend? What has caused a concentration of dye in the leaves?

Briefly describe the experiment and make a diagram of the cross section.

[1] A plant with a pale stem, such as jewelweed (*Impatiens*), is excellent for this exercise.

THE LEAF

Exercise 30

LEAF VENATION

Using leaves of the garden geranium (*Pelargonium*) attached to their stems, identify the expanded *blade*, the leafstalk or *petiole*, and the pair of basal *stipules*. Observe the numerous *veins* extending to all parts of the blade. On which side of the blade are they more prominent? Why? From what point do the larger veins branch out? Compare this *palmate* venation with the *pinnate* venation of an elm leaf. How do they differ? Both of these leaves are *net-veined;* in all such leaves the ultimate veinlets end freely. Observe this feature (*m*) in a net-veined leaf with conspicuous venation, or in one that has been "skeletonized" by removal of the green tissue. Compare with a leaf showing *parallel* venation.

Draw a net-veined leaf with pinnate venation and one with palmate venation. Also draw a parallel-veined leaf. Make a detailed drawing (×10) of a portion, approximately 5 mm. square, of a net-veined leaf in which the ultimate veinlets are clearly visible. Make a similar drawing of a portion of a parallel-veined leaf.

Exercise 31

LEAF DIVISION, FORM, AND OUTLINE

Compare a *simple* leaf with one which is "compound," that is, one with a blade divided into separate *leaflets*. Compare pinnately divided leaves with those which are palmately divided. Select six simple leaves of diverse form and margin and choose from the following list the proper terms to describe each:

Form.—Orbicular, oval, oblong, linear, lanceolate, ovate, deltoid, cordate, reniform.

Margin.—Entire, serrate, dentate, crenate, undulate, lobed, incised.

Draw a pinnately divided leaf, a palmately divided leaf, and six simple leaves of diverse form and margin.

Exercise 32

LEAF TENDRILS AND LEAF THORNS

The thorns of the barberry are foliar structures. Note their position on the stem with reference to the dwarf branches that bear foliage leaves. Observe the stipular thorns on leaves of the common locust (*Robinia*). In the leaves of either the garden pea or the sweet pea, note the modification of the terminal leaflets to form tendrils. Why are the stipules so large? Stipular tendrils may be seen in the carrion flower (*Smilax herbacea*).

Draw a portion of a shoot of the barberry showing foliar thorns. Also draw an entire leaf of the common locust, garden pea or sweet pea, and carrion flower.

Exercise 33

INSECTIVOROUS PLANTS

Study leaves of any species of pitcher plant and note the adaptation for holding water. Observe the hood and the stiff downward-pointing hairs inside. Examine (*m*) leaves of the sundew with their many "tentacles," each terminating in a knob-like gland. If an insect has been caught, observe the incurving of the tentacles.

Make a drawing of the leaf of a pitcher plant and of the sundew, the latter enlarged.

Exercise 34

LEAF STRUCTURE

Examine (*hp*) a temporary or a prepared slide showing a cross section of a typical leaf and identify its principal tissues. Note on both sides of the leaf a single layer of *epidermal cells* with a waxy deposit on their outer walls forming the *cuticle.* Do these cells contain chloroplasts? Beneath the upper epidermis may be seen one or two layers of elongated *palisade cells.* Below these is the *spongy tissue* made up of loosely arranged cells with large *intercellular spaces.* The palisade and spongy tissue together comprise the *mesophyll* region of the leaf. Do the cells of the mesophyll have chloroplasts? Find a *vein* and note that it consists of two kinds of vascular tissue, *xylem* and *phloem,* the former lying above the latter. How may these be distinguished? Small openings may be seen in the lower epidermis, and sometimes in the upper epidermis as well. These are *stomata,* to be studied below.

Make a drawing of a portion of the cross section studied, showing each of the tissues identified.

With a sharp scalpel, strip a piece of epidermis from the lower surface of a leaf and prepare a temporary mount. Note (*lp*) the form of the epidermal cells and the presence of *stomata.* Observe (*hp*) that a stoma consists of a slit bounded by a pair of *guard cells.* On which side is their cuticle thickest? Do they contain chloroplasts?

Draw a stoma as seen in surface view with some of the surrounding cells of the epidermis.

Exercise 35

DEMONSTRATION OF TRANSPIRATION

Insert a shoot of a potted plant[1] into a large Erlenmeyer flask and fasten with a split cork. Water the soil well, and in a short time observe the condensation of water vapor on the inside of the flask. Where did this water come from? Draw the apparatus and explain the results of the experiment.

Exercise 36

LIFTING FORCE OF TRANSPIRATION

Using a vigorous potted plant of sunflower, tomato, or geranium, cut the stem under water previously boiled and cooled to room temperature. Obtain a piece of glass tubing about 60 cm. long and with an outside diameter about that of the stem of the plant. Connect the glass tube to the stem under water by means of a short piece of heavy rubber tubing, being sure that the connection is tight. With your finger over the lower end of the glass tubing, so as to keep it filled with water, place it in a bottle of mercury. Support with ring stand and clamp. During the course of the next day or two, observe the height to which the mercury is drawn into the glass tube. What force or forces were responsible?

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[1] A sunflower, tomato, or geranium will answer the purpose well.

Exercise 37

DEMONSTRATION OF GUTTATION

Place a pot of well-watered nasturtium or oat seedlings under a bell jar and keep in a cool, dark situation. After an hour or two note the exudation of water. Exactly where on the leaves do the droplets of water form? What is the cause of their formation? How does guttation differ from transpiration?

Exercise 38

NECESSITY OF LIGHT IN PHOTOSYNTHESIS

Place a potted plant having fairly large, thin leaves in the dark for 24 hours. Then fasten a light screen[1] on one of the younger leaves and place in a well-illuminated situation for several hours. Remove the light screen from the leaf and the leaf from the plant. Extract the chlorophyll from the leaf by placing it in alcohol and warming on a water bath for half an hour. After the leaf is entirely bleached, wash in water and place in a solution of iodine. Observe which parts become dark colored and thus show the presence of starch. Note that no starch is formed in the covered portion of the leaf. What does this experiment prove?

Write up the results of your experiment and make a sketch of the leaf.

Exercise 39

PROPERTIES AND CONSTITUENTS OF CHLOROPHYLL

Prepare an alcoholic solution of chlorophyll, as in the last exercise, and pour it into a test tube. What is its color by transmitted light, that is, when light shines through it? What is its color by reflected light? This may be determined by holding the tube against a dark background and allowing bright light to shine upon the liquid. This property of chlorophyll is known as *fluorescence*. Pour off half of the solution in the test tube and replace with an equal quantity of benzene. Shake the mixture well and allow it to stand. The two liquids will gradually separate, the benzene going to the top of the tube and the alcohol to the bottom. After separating, what is the color of the two liquids? Which has extracted the greater part of the green pigments (*chlorophyll a* and *b*) and which the yellow pigments (*carotin* and *xanthophyll*)? Why do the green and the yellow pigments separate in this experiment?

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[1] The light screen should be one which will keep light away from opposite sides of a portion of the leaf, but at the same time permit free access of air from below. Ganong's smaller light screen is very satisfactory.

Exercise 40

NECESSITY OF CHLOROPHYLL IN PHOTOSYNTHESIS

Obtain a plant with variegated leaves, such as a silver-leaved geranium, and expose it to the light for several hours. Then remove one of the leaves, draw an outline of it, and also draw a line separating the green portion from the white portion. Extract the chlorophyll, as directed in Exercise 38, and make another drawing of the leaf, shading the portion that shows the presence of starch. How does the distribution of starch compare with the distribution of chlorophyll in the living leaf?

Exercise 41

NECESSITY OF CARBON DIOXIDE IN PHOTOSYNTHESIS

Obtain two vigorous potted plants of geranium which have been kept in darkness for 24 hours. Place each plant on a ground-glass plate under a tubulated bell jar having a one-hole rubber stopper to fit. Insert into each of the stoppers a calcium chloride tube. Fill one tube with soda lime crystals and also place a small dish containing soda lime crystals under the bell jar. Fill the other tube with sawdust or gravel. Make the connection between each bell jar and glass plate airtight with stopcock wax. Place both plants in a well-lighted situation, but not in direct sunlight, for 4 or 5 hours. Then remove a leaf from each plant and test for starch, as in Exercise 38. The soda lime absorbs carbon dioxide from the air.

Exercise 42

RELEASE OF OXYGEN IN PHOTOSYNTHESIS

Place two or three shoots of waterweed (*Elodea*) in a beaker of water. Fill a test tube with water and, holding your thumb over its open end, invert the tube and lower it into the beaker. Then push the cut ends of the shoots a short distance into the tube and place the apparatus in bright sunlight. The gas bubbles that arise from the cut ends of the shoots will gradually displace the water in the test tube. Count the number of bubbles arising per minute from one of the plants; then shade the apparatus and after several minutes count again. After the test tube has become nearly filled with the gas, remove the plants, cork the tube, and take it out of the water. Prepare a glowing splinter of wood, plunge it into the tube, and note its bursting into flame for an instant, thus proving the evolved gas to be oxygen.

Make a drawing of the apparatus and describe the results of your experiment.

Exercise 43

TESTS FOR FOOD SUBSTANCES

After making each of the following tests, describe the method of procedure and state the results obtained.

Starch.—Place a piece of starch the size of a pea in a test tube, fill two-thirds full of water, and shake. Add a few drops of iodine solution (iodine crystals dissolved in a 2 per cent aqueous solution of potassium iodide), and note the color reaction. Test a potato, a parsnip, and various seeds for starch.

Sugar.—Fill a clean test tube about one-quarter full of Fehling's solution,[1] bring to a boil, and add a few drops of a solution of grape sugar[1] in water. Reboil if no color change is immediately apparent. Test an apple, a beet, or an onion for sugar.

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[1] Take equal parts of a 1.5 per cent solution of cupric sulphate, an 8 per cent solution of sodium potassium tartrate, and a 6 per cent solution of sodium hydroxide. These solutions can be prepared in advance, but should not be mixed together until needed for use.

Protein.—Place a very small quantity of raw white of egg in a test tube, fill half full of water, and shake. Add about 2 cc. of a strong solution of potassium hydroxide, and boil for a few seconds. Then add a few drops of a strong solution of copper sulphate, shake well, and observe the color reaction. Test ground beans, corn, or peanuts for protein.

Fat.—Place a small quantity of corn meal, peanut butter, or other food containing fat in a test tube, fill half full of ether, and shake. Carefully pour off the liquid in a flat dish and place outside the window until the ether has evaporated. What is left?

Exercise 44

DIGESTION

Place a piece of starch the size of a pea in a test tube, fill two-thirds full of water containing the enzyme diastase (1 gram of dry diastase of malt to 1,000 cc. of water), and shake. In another test tube place several small pieces of hard-boiled white of egg, and fill two-thirds full of water containing hydrochloric acid and the enzyme pepsin (1 g. of dry pepsin to 1,000 cc. of a 0.2 per cent solution of hydrochloric acid).

Put both tubes in a water bath or in an incubator and keep at a temperature of approximately 40°C. After several hours observe the appearance of the material in the tubes. What happens to the starch and protein? Test the liquid in the first tube for starch and for sugar (see Exercise 43).

Describe the experiments and write a statement as to just what the process of digestion involves.

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[1] If cane sugar is used, add 2 or 3 drops of dilute sulphuric acid (1 part sulphuric acid to 5 parts water) to 5 cc. of the sugar solution and boil. Then proceed as with the grape sugar.

Exercise 45

NECESSITY OF SOIL SALTS

Grow some seedlings of buckwheat, tomato, or some other favorable plant on a paraffined wire screen which rests on a jar completely full of distilled water. Obtain four jars or widemouthed bottles with flat corks to fit and make several holes in each cork. Prepare a normal nutrient solution by dissolving in 1,000 cc. of distilled water: 1 g. calcium nitrate, 0.25 g. potassium chloride, 0.25 g. magnesium sulphate, 0.25 g. potassium phosphate (monobasic), and a few drops of ferric chloride solution. Prepare a nitrogen-free nutrient solution by substituting 1 g. calcium sulphate for the calcium nitrate. Prepare a phosphorus-free nutrient solution by dissolving in 1,000 cc. of distilled water: 1 g. calcium nitrate, 0.5 g. potassium chloride, 0.5 g. magnesium sulphate, 0.5 g. calcium sulphate, and a few drops of ferric chloride solution.

Wrap each bottle with opaque paper to prevent the growth of algae. Fill one bottle with the normal nutrient solution, another with the N-free solution, a third with the P-free solution, and a fourth with distilled water. Select seedlings as near the same size as possible and insert several in each bottle through the holes in the cork so that the roots are in the liquid. Plug absorbent cotton into the holes to support the stems. Place the plants in a warm, moderately bright situation. Renew the amount of liquid used by the plants every other day and aerate with an atomizer bulb. Change the solutions every two weeks.

Compare the relative growth and general health of the plants over a period of a month or more.

Exercise 46

NECESSITY OF OXYGEN IN GROWTH

Place a dozen young oat seedlings in one end of a large U tube with the roots toward the opening. Insert a loose plug of wet absorbent cotton, push into the tube for a distance of about an inch, and close the opening with a cork. Similarly prepare another U tube. Place the open end of one of the tubes in a jar of water and support with a stand and clamp. Into the open end of the other U tube place a little dry pyrogallic acid and insert a dry cotton plug. Now place this end of the tube into a jar containing a 10 per cent solution of potassium hydroxide, and place the apparatus in a warm, dark situation. Within an hour or two observe that the black solution (potassium pyrogallate) has risen in the tube, having absorbed the oxygen present there. Approximately what proportion of the air originally present in the U tube has been absorbed? After several days compare the growth of the seedlings in the two tubes. Why has the level of the water in the one tube remained approximately constant? Why was it necessary to keep the seedlings in darkness?

Draw the apparatus; state and explain the results of the experiment.

Exercise 47

RELEASE OF CARBON DIOXIDE IN RESPIRATION

Follow the same method as in the last exercise, but omit the pyrogallic acid. The solution of potassium hydroxide will leave the oxygen for use by the seedlings but will absorb any carbon dioxide as fast as it is given off. After several days, observe the height of the liquid in both tubes, and explain. The rise of the solution during this period was gradual. Why? What proportion of the air originally present in the tube has been absorbed? Why has the liquid gone no higher?

Exercise 48

PRODUCTION OF HEAT DURING RESPIRATION

Soak a pint of oats or wheat in water overnight, but not for more than 16 hours. Kill one half by immersing them in boiling water for 5 minutes and then cool in running water. Sterilize both lots by a short treatment with a 3 per cent formaldehyde solution, after which wash thoroughly. Fill an ordinary vacuum bottle with the living seeds to within 3 cm. of the neck. Insert a thermometer so that its bulb reaches the center of the bottle, and support it in the neck by means of a cotton plug. Similarly prepare a second vacuum bottle with the killed seeds. Keep both bottles at about 28 to 30°C. and take several readings a day at regular intervals during the next 4 or 5 days.

Exercise 49

LOSS OF WEIGHT DURING RESPIRATION

The object of this experiment is to demonstrate that respiration results in a loss of weight when photosynthesis is not possible. Weigh 20 air-dried seeds of pea or wheat and germinate in darkness. Calculate the percentage of water in these air-dried seeds by taking 10 g. of seeds from the same lot, placing them in a drying oven for a day or two at 110°C., and then weighing again. After 10 days weigh the seedlings and calculate the percentage of increase over their air-dried condition. To what is this increase due? Then put the seedlings in the oven for 48 hours at 95°C. Compare the dry weight of the seedlings with the calculated dry weight of the seeds from which they have developed. What is the percentage of decrease? What was the source of the substance lost during germination? In what form was it lost? How would this loss have been replaced under natural conditions?

Exercise 50

RESPONSE TO GRAVITY

Obtain two pieces of glass about 15 cm. square, two or three pieces of blotting paper the same size, and some seeds of radish or mustard. Moisten the blotting paper and place nine seeds on it, spacing them evenly. Place the blotters between the two glass plates and tie together with a string. Stand the plates upright in a shallow dish of water and keep in a warm, moist situation. After the seeds have germinated, notice the growth direction taken by the roots. Then invert the plates so that the roots are pointing in the opposite direction, and after several days observe what changes have taken place. To what stimulus have the roots responded?

State what was done and illustrate your results with a drawing of one of the seedlings before and after the growth direction was changed. Why had the stimuli of moisture and of light nothing to do with the results in this experiment?

Draw a potted seedling of sunflower or of scarlet runner bean which has been placed in a horizontal position in a dark place for a day or two. Explain the growth direction of the stem tip and the orientation of the leaves. Why was the seedling kept in the dark?

Exercise 51

RESPONSE TO LIGHT

Examine and sketch plants which have been exposed to one-sided illumination for several days. Explain the growth direction of the stem tip and the orientation of the leaves. Of what advantage is this reaction to the plant? If a clinostat is available, place on it a potted plant which has grown in a situation with good overhead illumination, place the plant where the light will strike it largely from one side, and set the clinostat in motion. Explain the results obtained.

ENVIRONMENTAL RELATIONS

Exercise 52

HYDROPHYTES

Plants that grow in water or in very wet places are called *hydrophytes.* Study submerged water plants having dissected leaves. Of what advantage is this condition to the plant? Examine (*lp*) a cross section of the stem of a hydrophyte. Note the presence of large air spaces and the reduction of vascular tissue. Explain. Do you find mechanical tissue? Do submerged hydrophytes have stomata? Do they have a cuticle? Look at floating leaves of water lilies. A cross section will reveal a marked difference in internal structure between the upper and lower portion of the leaf. Where are the stomata? If plants of mermaid weed (*Proserpinaca palustris*) or of a similar hydrophyte are available, note the striking difference in form between the submerged leaves and those of the same plant growing into the air.

Make drawings of several different kinds of hydrophytic leaves and write an account of your observations.

Exercise 53

XEROPHYTES

Xerophytes are plants that live in dry places. They are structurally adapted to live under conditions of little available moisture. Observe, in the field if possible, various types of xerophytes, such as those with reduced leaves, with hairy leaves, with stiff or leathery leaves, and with succulent leaves or stems. Why are many xerophytes small leaved or leafless? To what is the fleshy character of succulent plants due? To what is the stiffness of leathery leaves due? Examine (*hp*) cross sections of a leaf of one or more of the plants studied and note all the ways in which the internal structure differs from that of an ordinary mesophytic leaf.

Draw an example of each of the different types of xerophytes seen. Write an account of your observations, stating in each case exactly how the plant is adapted to endure the conditions under which it lives. Explain fully the significance of all of the adaptive features seen.

Exercise 54

PLANT ASSOCIATIONS

One or more plant associations should be studied in the field. Careful notes should be taken on the trip and a detailed report written upon your return. Because conditions vary so greatly in different regions, it is obvious that specific directions cannot be given. A few general suggestions, however, will be helpful. The following outline will serve as a guide in writing your report. It will also give you an idea of what to look for.

- Location of area
- Description of habitats studied
  - Rainfall and humidity
  - Character of the soil: depth, physical composition, amount of humus, drainage
  - Light
  - Special features
- Character of the associations
  - Kinds represented; interrelationships
  - List of plants occurring in each association; dominant species
  - Adaptation of plants to conditions in each habitat
- Succession of associations
  - Factors causing succession
  - Evidence of succession from plants themselves
  - Proof that a climax association is or is not present

Exercise 55

SAPROPHYTIC SEED PLANTS

Observe specimens of the Indian pipe, pinesap, snow plant, and any other available forms. In each case, the living plant contains no chlorophyll. Of what significance is the presence of scales? How do these plants obtain their nourishment?

Make a drawing of any one of the plants studied.

Exercise 56

PARASITIC SEED PLANTS

Well-known parasitic seed plants are the dodder and the mistletoes. Both attack a number of different kinds of plants. Note the way in which the parasite is attached to its host. Does the parasite have leaves, and if so, are they conspicuous or reduced? Of what significance is this? Is chlorophyll present? Does the parasite have any connection of its own with the soil? How does it obtain its water and its food? Examine (*lp*) a prepared slide showing a cross section of the stem of the parasite attached to its host. What tissue is penetrated?

Make drawings of the forms studied, showing a portion of the host as well as the parasite.

Exercise 57

RECIPROCAL PARASITISM

Examine root systems of bean, clover, alfalfa, or of some other legume, and note the numerous swellings. These *tubercles* or *nodules*, as they are called, contain bacteria which have invaded the roots from the soil, and the roots have responded to their presence by undergoing local enlargement. Upon what do you think the bacteria live?

These bacteria can form nitrogenous compounds directly from the free nitrogen of the air. Of what advantage is this to the legume? How is the legume benefited by the presence of the bacteria? Is the relation between them one of symbiosis? Why?

Sketch a portion of the root system showing the tubercles.

THE FLOWER AND FRUIT

Exercise 58

FLORAL PARTS

Study the flowers which have been provided for this exercise, distinguishing between the outer green *calyx*, the conspicuous *corolla*, the *stamens*, and the *pistil*. Note the symmetrical arrangement of the floral parts with reference to one another and their relation to the *receptacle*, or broadened stem tip upon which they are borne. The calyx is made up of individual *sepals*. What is their form and number? To what extent do they resemble foliage leaves? The corolla is composed of *petals*. What is their form, number, and color? Are they separate and distinct from one another, or united to form a tube? Are all the petals alike in form? How many stamens are present? To what are they attached? Distinguish between the pollen-bearing portion or *anther* and the stalk or *filament*.

Examine the pistil, the central organ of the flower. Distinguish between the lower bulbous *ovary* and the slender stalk-like *style* arising from it. To what extent is the style branched? Study (*m*) the *stigma* or *stigmatic surface*, the portion of the style which is receptive to pollen. What is its character? Is the corolla attached near the base of the ovary so that the ovary is inside the corolla, or is it attached to the top of the ovary so that the ovary is below the corolla? Cut an ovary in half transversely and examine (*m*). How many *locules* (cavities) are present? Note the small white *ovules*. Are there few or many? To what are they attached? Is there any evidence that the pistil is *compound*, that is, made up of two or more *carpels* (simple pistils) that have become more or less united?

Write a detailed description of the flower you have studied, including answers to all of the questions asked. Draw to scale a front and a side view of a single flower, a stamen, the pistil, and a cross section of the ovary. Also construct a floral diagram.

Exercise 59

ANTHER AND POLLEN

Examine (*lp*) a prepared slide showing a cross section of a lily anther and note the two large *pollen sacs* containing numerous *pollen grains*. How are the pollen grains liberated from the anther? Examine (*hp*) a single pollen grain and identify the *tube nucleus* and the *generative nucleus*. How can you tell them apart? Mount pollen grains, such as those of nasturtium, sweet pea, or lily, which have been growing in a 10 per cent solution of cane sugar, and observe (*lp*) the development of the pollen tubes.

Make a diagram of a cross section of an anther. Make a drawing of a section of a pollen grain. Also draw a germinating pollen grain.

Exercise 60

OVULE AND EMBRYO SAC

Obtain a prepared slide showing a cross section through the ovary of a lily, or of some other favorable form, and note (*lp*) the position of the ovules. To what are they attached? Find an ovule which has been cut lengthwise through the middle and note (*hp*) the large *embryo sac* surrounded by one or two *integuments*. Find the *micropyle*. What is its position with reference to the stalk of the ovule? Count the nuclei in the embryo sac; if it is not mature there will be less than eight. In a mature embryo sac identify at the micropylar end the egg apparatus consisting of an *egg* and two *synergids*. Can you find two large *polar nuclei* or, if these have already fused, the single *fusion nucleus?* At the other end of the embryo sac the three *synergids* may be seen.

Make a drawing of a longitudinal section of an ovule with a mature embryo sac. Also draw one or more younger stages in development.

Exercise 61

DRY FRUITS

Study examples of the following types of dry fruits: achene, nut, follicle, legume, and capsule. In each case determine whether the fruit is *dehiscent* (opening at maturity) or *indehiscent*, one-seeded or many-seeded, and whether the pericarp is thick or thin. The pericarp is the ripened ovary wall. From how many carpels does each type of fruit develop? If the fruit undergoes dehiscence, how does this occur? Does the fruit exhibit any special features?

Draw one of each type of dry fruit studied.

Exercise 62

FLESHY FRUITS

Study examples of the following types of fleshy fruits: drupe, pome, berry, aggregate fruit, multiple fruit. In each case determine what part or parts of the flower have entered into the formation of the fruit. Make a cross section and a longitudinal section, noting the number of seeds and their place of attachment. Which of the fruits studied develop from a superior ovary and which from an inferior ovary? How can you tell? Which are accessory fruits and why? How do aggregate fruits and multiple fruits differ from simple fruits? In which fruits does the pericarp consist of more than one layer?

Make drawings of each type of fleshy fruit studied.

Exercise 63

FLORAL EVOLUTION AND POLLINATION

Study the flowers that have been provided and in each case note the following facts before drawing: (1) Perianth of one whorl of parts or differentiated into calyx and corolla. (2) Corolla choripetalous or sympetalous, regular or irregular. (3) Color and number of sepals. (4) Color and number of petals. (5) Number, arrangement, and place of attachment of stamens. (6) Number of carpels and their degree of union. (7) Ovary superior or inferior; number of locules; kind of placentation. (8) Special features, especially those relating to pollination.

Make such drawings of each flower studied as will illustrate the relation of the floral parts to one another and write a complete description. Tell in what ways each flower is primitive from the standpoint of floral evolution and in what ways it is advanced. Explain precisely how pollination takes place.

SEEDS AND SEEDLINGS

Exercise 64

SEED STRUCTURE

Obtain a soaked bean seed and observe (*m*) its external features. The large scar, or *hilum*, represents the place of attachment of the seed to the pod. At its one end is the *micropyle*, a minute pore; at its other end is the blister-like *raphe*. As in other seeds developed from curved ovules, the raphe is the place where the stalk has united with the integument. Remove the seed coat, or *testa*, and separate the two large fleshy *cotyledons*. Lying between them is the *hypocotyl*, a short stem at the upper end of which may be seen a small bud called the *plumule*. Note carefully the point of attachment between the cotyledons and the hypocotyl. The hypocotyl, plumule, and cotyledons constitute the *embryo*. In what part of the seed is most of the food stored?

Draw a whole bean as seen in face and in side view (×2 or larger). Make a drawing of the seed split open to show the parts of the embryo.

Obtain a soaked grain of corn, cut it in half lengthwise at right angles to its broad face, place a drop of weak iodine solution on the cut surface, and examine (*m*). The *embryo* is stained yellow, the starchy portion of the *endosperm* dark purple. The embryo has a single *cotyledon* which is in close contact with the endosperm. Identify the *hypocotyl* with the *plumule* at its upper end. Note the attachment between the hypocotyl and the cotyledon. Where in the corn grain is most of the food stored?

Make a drawing of the corn grain as seen in longitudinal section (×5).

Exercise 65

OTHER SEEDS

Study soaked seeds of pea, sunflower, squash, maple, castor bean, morning-glory, buckwheat, wheat or oats, and onion. Determine the following facts about each one: presence or absence of endosperm, number of cotyledons, cotyledons thick or thin, cotyledons straight or curved, development of the plumule, special features.

Record the results of your study in the form of a table.

Exercise 66

SEED GERMINATION

Examine seedlings of the common garden or kidney bean in various stages of development. From what part of the embryo has the root system arisen? Does the hypocotyl continue to grow after the primary root is formed, or does it remain short? Do the cotyledons appear above the surface of the ground, or do they remain inside the testa beneath the surface? Into what does the plumule develop? What finally happens to the cotyledons?

Make a series of drawings illustrating the development of the bean seedling and write an account of the same, answering the above questions.

Study several stages in the development of the corn seedling, noting the ways in which it differs from that of the bean. Distinguish between the primary root and the adventitious roots. From what part of the seedling do the latter arise? What is the function of the single cotyledon? What is the function of the endosperm? Does the hypocotyl continue to grow after the primary root has formed? Does the plumule develop relatively earlier or later than in the bean seedling?

Make several drawings to illustrate the development of the corn seedling and briefly describe.

Exercise 67

OTHER SEEDLINGS

Make a comparative study of such seedlings as those of the pea, scarlet runner bean, sunflower, squash, maple, castor bean, morning-glory, buckwheat, wheat or oats, and onion. Determine the following facts about each one: whether the hypocotyl continues to grow after the root is formed; whether the cotyledons (or cotyledon) are pulled out of the ground and, if so, the means by which this is accomplished; the development of the plumule with reference to the development of the other parts of the embryo; the role and fate of the cotyledons (or cotyledon); special features.

Write a description of the development of each seedling studied.

Exercise 68

SEED DISPERSAL

Examine dry fruits, such as those of the sweet pea, which upon ripening forcibly discharge their seeds into the air. Note the presence of structures to facilitate dispersal by the wind in the winged seeds of catalpa, winged fruits of maple, ash, and elm, downy seeds of milkweed, and downy fruits of dandelion and thistle. Place achenes of the dock in water and observe the corky floats which give them buoyancy. Also float in a vessel of water a dried receptacle of the lotus with its many embedded achenes. Observe the barbed achenes of the beggar-ticks and the heads of cocklebur and burdock. Examine (*m*) the individual barbs. How are these fruits dispersed?

Draw an example of each type of dispersal seen.

MENDELIAN LAWS OF HEREDITY

Exercise 69

PRINCIPLE OF SEGREGATION

When starchy corn is crossed with sweet corn, starchiness is found to be the *dominant* character and sweetness the *recessive* character. When the hybrids are interbred, however, both kinds of grains make their appearance. Examine ears of corn produced by such hybrids. Count the number of each kind of grains in four rows on the ear. What proportion of them are starchy (plump) and what proportion are sweet (shriveled)? How does this compare with the theoretical ratio expected on the basis of Mendel's principle of segregation? If you were to remove some grains of each kind from the ear you are studying, plant them, and self-pollinate each of the resulting plants, what kind of offspring would you expect from the starchy corn and what kind from the sweet corn? Would all the starchy corn behave alike under these conditions? Explain.

Write a complete explanation of this experiment in terms of Mendelian heredity.

Exercise 70

PRINCIPLE OF FREE ASSORTMENT

When corn with yellow starchy endosperm is crossed with white sweet corn, the resulting seeds are yellow and starchy. But when the hybrids are interbred, a segregation takes place that results in the appearance of four different types of grains, *viz.*, yellow starchy, yellow sweet, white starchy, and white sweet. Study ears of corn showing such segregation and count the number of grains of each type. In what numerical proportion does each occur?

How does this compare with the theoretical dihybrid ratio which would be expected on the basis of Mendel's principle of free assortment? Considering only color, what is the ratio between the yellow and the white grains? Then considering only starchiness, what is the ratio between the starchy and the sweet grains?

Write a complete explanation of this experiment in terms of Mendelian heredity.

THALLOPHYTES: 1. ALGAE

Exercise 71

BLUE-GREEN ALGAE

Examine (*hp*) colonies of *Gloeocapsa*, *Nostoc*, and *Oscillatoria*, noting the form and arrangement of the cells. What is their color? How is the color distributed? Do you find chloroplasts in the cells? Is a definite nucleus present? Note carefully the presence or absence of a mucilaginous sheath. Does it surround individual cells or the entire colony? In *Nostoc*, look for peculiar dead cells, called *heterocysts*, that occur singly but at rather frequent intervals. These mark places where the colony will break. If living *Oscillatoria* is studied, observe the peculiar oscillating movements of the filaments.

Make drawings of the forms studied.

Exercise 72

PROTOCOCCUS

Protococcus, a unicellular form, is one of the simplest of the green algae. Scrape a small quantity of living *Protococcus* from a piece of bark, mount in a drop of water, and examine (*lp*). Note the numerous green bodies, each representing a cell or a small group of cells. How does their color differ from that of the algae studied in the last exercise? Examine (*hp*) the structure of a single cell, noting the cell wall and protoplast. The nucleus is not visible. The green coloring matter, *chlorophyll*, is confined to a lobed peripheral *chloroplast*. Find cells that have divided into two, three, or four parts. These illustrate reproduction by cell division, a method called *fission*. The cells arising from a single cell are only temporarily associated, soon separating and carrying on an independent existence.

Draw a single cell of *Protococcus* and several groups of cells.

Exercise 73

ULOTHRIX

Ulothrix is a simple multicellular green alga, the body having the form of an unbranched filament. Note (*lp*) its length and the shape of the individual cells. Each cell contains a central nucleus which is obscured by the peripheral band-like chloroplast. Carefully examine (*hp*) the chloroplast, noting the presence on it of numerous *pyrenoids*, or centers of starch formation.

Study the formation of *zoospores*, comparing the cells containing them with the vegetative cells. How do these arise? If living material is available, observe the escape and behavior of the zoospores. How many cilia does each possess? Each zoospore has the capacity of directly producing a new plant. Also study the formation of *gametes*, comparing their size with that of the zoospores. The gametes escape from the cell in which they are formed, swim through the water by means of two cilia, come together in pairs, and fuse to form a *zygote*. The activity of the gametes may be studied if living material is available.

Draw a portion of the vegetative filament as well as stages in the formation of zoospores and of gametes.

Exercise 74

DRAPARNALDIA

This green alga is a branching filament. Place a bit of material on a slide and spread it out with your dissecting needles. Prepare a temporary mount and examine (*lp*). How do the cells of the branches differ from those of the main filament? Observe (*hp*) that each cell contains a peripheral band-like chloroplast with many pyrenoids.

The chloroplast obscures the central nucleus. Reproduction is similar to that of *Ulothrix*.

Draw a portion of the branching filament of *Draparnaldia*.

Cladophora is also a branching filament, but the cells are much longer and have many nuclei in addition to the peripheral net-like chloroplast with its many pyrenoids. There is much less differentiation between the branches and the main filament than in *Draparnaldia*. If necessary, *Cladophora* may be substituted for *Draparnaldia*.

Exercise 75

OEDOGONIUM

Oedogonium, like *Ulothrix*, has a vegetative body consisting of an unbranched filament, but the cells are longer in proportion to their width. Note (*lp*) the character of the filament and (*hp*) that of the individual cells. Observe the peripheral chloroplast with its many pyrenoids and, if visible, the central nucleus. The entire contents of a vegetative cell may become a single large zoospore which escapes and swims by means of a crown of cilia. The formation of zoospores may be readily studied in living material. Find a large globular cell containing an *egg* and note the accumulation of food material in it. Find a group of very short cells, each with two *sperms*. The sperms are small gametes that escape and swim by means of a crown of cilia. When a sperm enters the egg, the latter is said to be fertilized. Compare the appearance of a fertilized egg with one which is unfertilized.

Make drawings to show all features seen.

Exercise 76

VAUCHERIA

Vaucheria is a green alga whose filamentous body is peculiar in lacking cross walls. Observe (*lp*) the branching of the filament and (*hp*) its detailed structure. Numerous small nuclei and chloroplasts are scattered throughout the cytoplasm; oil droplets are also present. If living material is available, the formation and escape of the zoospores may be studied. They are large and entirely covered with cilia. Sex organs are borne on short lateral branches, one or more *oögonia* (female organs) surrounding an *antheridium* (male organ). How are the sex organs separated from the vegetative filament? The antheridium produces numerous biciliate sperms, while the oögonium contains a single nonmotile egg.

Make drawings to illustrate the features seen.

Exercise 77

SPIROGYRA

Examine (*lp*) filaments of *Spirogyra,* one of the commonest of the green algae. Are the filaments branched or unbranched? What is the shape of the cells? Note (*hp*) that each cell contains one or more spiral, ribbon-like chloroplasts with many pyrenoids. If the nucleus is not visible, a drop of weak iodine solution may render it so. What is its position in the cell? Endeavor to see the strands of cytoplasm extending outward from the nucleus to the cell wall. If conjugating material is available, observe the short lateral tubes put out from the cells of two adjacent filaments, the passage of the contents of one to fuse with those of the other, and the resulting formation of zygotes. This alga is peculiar in that both of the fusing gametes are large and nonciliated, although one is active and the other passive.

Draw two or three vegetative cells and several stages in conjugation.

Exercise 78

ECTOCARPUS

Ectocarpus is one of the simpler brown algae. Observe (*lp*) the branching filamentous body, noting (*hp*) the structure of the cells. Biciliate zoospores are borne in globular unicellular *sporangia;* biciliate gametes are produced in elongated multicellular *gametangia.* Identify both sporangia and gametangia. What is their position on the filament?

Draw a sporangium and a gametangium, each attached to its vegetative filament.

Exercise 79

FUCUS

The rockweeds are coarse leathery forms growing along seacoasts. Observe the vegetative body of *Fucus*, noting its color, form, method of branching, and manner of attachment. Are air bladders present? What is their function? Examine (*m*) the swollen tips of certain of the branches and find the numerous pores, each leading to a *conceptacle*, or chamber containing sex organs. Study (*lp*) a longitudinal section through a conceptacle and note the numerous branching filaments bearing *antheridia* (male organs),[1] the large *oögonia* (female organs), and the great number of sterile filaments. Each oögonium gives rise to eight eggs which are extruded into the water to be fertilized. The sperms are biciliate, but the eggs are nonmotile.

Make a habit sketch of *Fucus* and a drawing of a cross section through a conceptacle.

Exercise 80

OTHER BROWN ALGAE

Examine other brown algae, noting their color, texture, differentiation of the body, and special features. Make habit sketches of several different types.

Exercise 81

RED ALGAE

The red algae are more delicate than the brown algae and are not so large. Examine filamentous, ribbon-like, and plate-like forms, noting the degree to which the body is differentiated. Make habit sketches of several different types.

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[1] Depending upon the species, the antheridia and oögonia may occur in the same conceptacle, in different conceptacles on the same plant, or on different plants.

THALLOPHYTES: 2. FUNGI

Exercise 82

BACTERIA

Mount a drop of water containing decaying organic matter and examine under the microscope. A great deal of patience may be required to find the bacteria. Use the highest magnification only and very little light. Look for minute colorless bodies, some of which may be moving rapidly across the field of vision. Try to distinguish between the different types seen. Examine (*hp*) prepared slides of stained bacteria. Distinguish between the spherical (*coccus*), rod-shaped (*bacillus*), and curved or spiral (*spirillum*) forms. Observe in each case whether the cells are separate or arranged in colonies, such as chains, plates, etc. If cilia are visible, note their number and distribution.

Make drawings of all available types studied.

In order to prove that the decay of organic matter is brought about by bacteria, perform the following experiment. Fill two clean test tubes with cooled and filtered broth made from meat or beans. Leave one of the tubes open. Reboil the broth in the second tube and immediately plug with sterilized cotton. After several days compare the odor and appearance of the liquid in each tube and examine (*hp*) for bacteria. Where decay has taken place, how do you account for the presence of the bacteria? Did the liquid in the second tube have access to air? What was the effect of the boiling? Under what conditions will food remain unspoiled?

Exercise 83

SAPROLEGNIA

The vegetative body of the fungi, exclusive of the bacteria, nearly always consists of a mass of branching filaments called a *mycelium*. Examine (*m*) the mycelium of *Saprolegnia* growing upon a dead fly put in water previously taken from a pond or ditch. Mount a small portion of it and examine (*lp*). Observe the colorless branched filaments. Are cross walls present? The sporangia are slender terminal cells. Find a sporangium and observe (*hp*) the escape of the numerous biciliate zoospores. Study the sex organs, if present. How many eggs are in the oögonium? In what ways does *Saprolegnia* resemble certain algae already studied?

Draw a portion of the mycelium, a sporangium, and the sex organs.

Exercise 84

ALBUGO

Examine (*m*) plants of shepherd's-purse infected with *Albugo*, observing the masses of white sporangia breaking through the epidermis. Study (*lp*) cross sections of an infected leaf or stem and note the intercellular mycelium giving rise beneath the epidermis to erect sporangiophores, from the ends of which small globular sporangia are cut off in chains. How are the sporangia liberated from the host? What do they produce? If preparations showing sex organs are available, examine (*hp*). The oögonium produces a single egg that becomes a heavy-walled zygote.

Draw a portion of an infected plant (×2). Also draw a cross section of an infected leaf or stem, showing the mycelium, sporangiophores, and sporangia. Draw an oögonium or a zygote.

Exercise 85

BREAD MOLD

Examine (*m*) bread mold (*Rhizopus*) growing on moist stale bread, noting the white filamentous body of the fungus, called the *mycelium*, and the clusters of upright branches arising from it. The latter bear large, globular, terminal sporangia containing numerous spores that turn black as they ripen. How are the spores dispersed? Mount a bit of the mycelium on a slide and examine (*lp*). Are cross walls present? Look for branched root-like *haustoria* through which nourishment is absorbed from the bread. Examine (*hp*) a sporangium not yet mature and note the dome-like wall cutting off the mass of spores from the stalk. How do the spores of the bread mold differ from those of the water mold and the algae previously studied?

Make a drawing showing a portion of the mycelium, a haustorium, and several sporangia. Also draw a single sporangium on a larger scale.

Study (*lp*) a prepared slide showing sexual reproduction in the bread mold. Find two adjacent filaments which have put out conjugating tubes toward each other and note (*hp*) the gamete at the tip of each tube. Find a later stage in which the gametes have fused to form a heavy-walled zygote.

Draw two or three stages illustrating conjugation in bread mold.

Exercise 86

YEAST

In a bottle of fermenting fruit juice containing yeast, note the numerous bubbles of carbon dioxide coming to the surface. Prepare a temporary mount and examine (*hp*) the yeast cells. How are they arranged? Is a cell wall present? Is chlorophyll present? Note the presence of *buds* and determine how these are formed. The nucleus is not readily visible; the large clear spaces inside the cells are vacuoles.

Draw several chains of yeast cells showing bud formation.

Exercise 87

PEZIZA

Observe the fleshy, cup-like fruiting bodies of *Peziza,* a saprophytic fungus whose mycelium lives in rich soil or in rotting wood. The fruiting body is called an *ascocarp.* Remove a very small portion of its inner lining and squeeze out under a cover glass. Observe (*lp*) the elongated sac-like *asci* with their *ascospores.* How many spores do you find (*hp*) in each ascus? Intermixed with the asci are numerous sterile filaments.

Draw an ascocarp and several asci.

Exercise 88

LILAC MILDEW

Obtain a lilac leaf infected with lilac mildew (*Microsphaera*) and observe (*m*) the mycelium growing upon its surface. Short haustorial branches penetrate the epidermal cells of the leaf and absorb nourishment from them. The spherical black bodies, if present, are reproductive structures called *ascocarps.* Remove a few of these from a leaf previously soaked in warm water for an hour, prepare a temporary mount, and examine (*hp*). Note the long, hook-like appendages. What is their function? Press gently on the cover glass and squeeze out some of the *asci*, each containing eight *ascospores.*

Make a sketch of the infected leaf and a careful drawing of one of the slightly crushed ascocarps.

Exercise 89

WHEAT RUST

Puccinia graminis is the cause of the most destructive rust disease of wheat. Examine (*m*) infected leaves of wheat and note the reddish-brown spots and lines on the surface. These are masses of *uredospores* produced by a mycelium living inside the leaf. Now examine (*m*) infected stems of wheat and observe the black masses of *teliospores*, produced somewhat later in the season. Scrape off spores of each kind from the host, prepare temporary mounts, and examine (*hp*). How do the uredospores and teliospores differ? Examine (*m*) an infected leaf of the common barberry (*Berberis vulgaris*) and observe the groups of *aecia* or cluster cups. On which side of the leaf do they occur? Study (*hp*) a prepared slide showing a cross section of the leaf of barberry cut through an aecium. Observe the large number of *aeciospores* arising in chains. How do they differ from the uredospores and and teliospores? Can you recognize the mycelium in the leaf tissues? Observe (*lp*) a *spermogonium*, one of the flash-shaped structures opening on the upper surface of the leaf. It produces a number of minute cells called *spermatia.*

Draw portions of an infected leaf and stem of wheat and of a leaf of barberry (×10). Also draw a uredospore, a teliospore, and a section through an aecium.

Exercise 90

MUSHROOMS

Obtain specimens of the common field mushroom (*Agaricus campestris*) and identify the *cap*, *stalk*, and *gills.* Note the *veil* that covers the gills in young stages. What is its relation to the *annulus*, or ring, on the stalk of the mature mushroom? The mushroom is a fruiting body (*sporophore*) arising from a mycelium that lives in rich soil. Remove the stalk from a. mature sporophore and place the cap, gills down, on a piece of paper. Do not disturb for several hours; then observe the spore print made by the spores falling on the paper. Cut a sporophore in half lengthwise and note the position and character of the gills. Do all of them extend from the center of the cap to its edge? With a safety-razor blade cut very thin sections perpendicular to the gills, prepare a temporary mount, and examine (*hp*). Observe along the gill margins the club-like *basidia* with their stalked *basidiospores.* In *Agaricus* each basidium bears two spores, but in practically all other mushrooms it bears four spores.

Draw a mature sporophore, a median section through it, and a greatly enlarged view of the gills showing the basidia.

Exercise 91

LICHENS

Examine various kinds of lichens, noting their color, form, texture, and growth habit. Distinguish between the *crustose* forms, which occur as incrustations on rocks and bark; the *foliose* forms, which are flat and leaf-like; and the *fruticose* forms, branching lichens that hang from trees or grow on the ground. A lichen consists of an alga living symbiotically with a fungus. Examine (*lp*) a cross section through the body of a lichen, distinguishing between the alga and the fungus. How are they associated? How does each lichen component derive benefit from its association with the other?

Sketch at least three different kinds of lichens and make a detailed drawing of a portion of a lichen body as seen in cross section.

BRYOPHYTES

Exercise 92 ✓

RICCIA

Examine (*m*) vegetative plants of *Riccia,* a simple liverwort, noting their form, color, and method of branching. Observe the grooves in the upper surface and the hair-like *rhizoids* and flat *scales* on the lower surface.✓ Sex organs are borne in the grooves, each sunken in a pit. A sperm from a male organ (*antheridium*) enters a female organ (*archegonium*) and fuses with the egg. The vegetative plant, bearing the sex organs, is called a *gametophyte.*

The zygote gives rise to a spore-producing plant, called a *sporophyte.* This develops inside the female sex organ. In *Riccia* the sporophyte consists only of a spherical case containing many small aerial spores. Observe (*m*) the row of sporophytes lying in one of the dorsal grooves of the gametophyte. Dissect out one or two of them, prepare a temporary mount, and examine (*lp*). Crush the sporophyte with a slight pressure on the cover glass and observe (*hp*) the dark colored, thick-walled spores. Study (*lp*) a longitudinal section through a nearly mature sporophyte embedded in the gametophyte. Note the large air chambers in the upper portion of the gametophyte. What is their function? How are the spores liberated? Upon germination, what do they produce?

Make a drawing of the gametophyte as seen from above (×5), showing the position of the sporophytes in the grooves. Also draw a longitudinal section of a sporophyte embedded in the gametophyte.

Exercise 93

MARCHANTIA

Study the thallus (gametophyte) of *Marchantia,* a common liverwort. Note its form and method of branching.

Where does growth take place? Compare (*m*) the appearance of the upper and lower surfaces. Find the *air pores*, the limits of the *air chambers*, and the filamentous *rhizoids*. If the thallus bears small cup-like structures (*cupules*), remove with a needle some of the small green *gemmae* contained within. Examine these (*lp*), noting their form and size. Examine (*lp*) a cross section of the thallus. Where are the air chambers found? Within the air chambers are numerous short filaments containing chloroplasts. What is their function? Find and examine (*hp*) an air pore. What is its function?

Draw an entire thallus (×2), a portion of the upper surface more highly magnified, a gemma, and a cross section of the thallus.

Study (*m*) plants bearing male and female receptacles. Do both kinds occur on the same plant? From exactly what part of the thallus do they arise? The *antheridia*, or male organs, are embedded in the disk of the male receptacle. The *archegonia*, or female organs, hang down between the rays of the female receptacle. On prepared slides find a single mature antheridium and a mature archegonium, both sectioned longitudinally. How do they differ in shape? In the antheridium note (*hp*) the stalk, the outer sterile jacket, and the central sperm-producing cells. In the archegonium note (*hp*) the stalk, the sterile jacket, the egg, and the slender neck. If the archegonium is not yet mature, a row of *canal cells* may be seen in the neck. How does one of the biciliate sperms get from the antheridium to the egg in the archegonium?

Draw a male and a female receptacle (×2); also draw a mature antheridium and a mature archegonium sectioned longitudinally.

The fertilized egg gives rise to a *sporophyte* which develops inside the archegonium. Examine (*lp*) a prepared slide showing a young sporophyte of *Marchantia*, distinguishing between the upper spore-producing portion and the lower sterile portion. In a nearly mature sporophyte, observe the anchor-like *foot*, the stalk or *seta*, and the spore-bearing *capsule*. What is the function of the foot? Study (*hp*) the spores and observe among them the elongated *elaters*, each with two spiral bands. What is the function of the elaters?

Draw a longitudinal section of a young and of a nearly mature sporophyte; also draw an elater and several spores more highly magnified.

Exercise 94

ANTHOCEROS

The gametophyte of this liverwort is simpler than that of *Marchantia*, being a thin flat thallus without air chambers. Note (*m*) the rhizoids on the lower surface. The sporophyte is tall, slender, and green, its foot being embedded in the gametophyte. If the sporophyte is mature, it will be split above into two parts to liberate the spores. What is the origin of the collar-like structure at the base of the sporophyte? Study (*hp*) a prepared slide showing either cross or longitudinal sections of the sporophyte and note the central column of conducting cells, the hollow cylinder of spore-producing tissue, and the outer green region.

Make a drawing of the sporophyte arising from the gametophyte (×4). Draw a section of the sporophyte showing its three regions.

Exercise 95 ✓

MOSSES

Examine (*m*) individual moss plants, noting the very simple stem and leaves. Wash away the soil from the lower end of the stem and observe (*lp*) the brown absorptive filaments called *rhizoids*. How many cells thick are the leaves? This plant body is a *gametophyte* because it produces gametes. These are formed in sex organs borne in a cluster at the upper end of the leafy stem. Both kinds of sex organs may occur in the same cluster or in different clusters, depending on the species. Examine (*lp*) preparations showing male organs or *antheridia*, and female organs or *archegonia*. Each antheridium produces many biciliate sperms: each archegonium, a single nonmotile egg. In the antheridium note the stalk and the sterile jacket, the latter enclosing many small sperm-producing cells. In the archegonium note the stalk and sterile jacket, the latter prolonged into a long slender neck. If the archegonium is not yet mature, a row of *canal cells* may be seen above the egg. How is fertilization accomplished?

Make a drawing of a shoot (×2 or larger) with its rhizoids below, and indicate the position of the sex organs. Also draw a single antheridium and a single archegonium.

From the fertilized egg there develops a *sporophyte* consisting of a *foot* embedded in the gametophyte, a long slender stalk or *seta*, and a terminal spore-bearing *capsule*. Examine (*m*) moss sporophytes, noting the hood-like *calyptra* and the lid, or *operculum*, both of which come off when the spores are shed into the air. What is the origin of the calyptra? Beneath the operculum is a ring of teeth forming the *peristome*. Examine this (*m*). What is its function? Mount some of the spores and note (*hp*) that each consists of a single thick-walled cell. Upon germination, the spore gives rise to a delicate green filament, the *protonema*. Examine (*m*) moss protonema growing upon moist soil. Mount a bit of it and examine (*lp*). Is the protonema branched or unbranched? Note carefully the character of the cross walls. Look for small buds which give rise to erect shoots.

Draw a moss sporophyte arising from the top of the gametophyte (×2 or larger). Make a drawing on a larger scale of a moss capsule with its operculum removed. Also draw a bit of moss protonema.

PTERIDOPHYTES

Exercise 96

LYCOPODIUM

Examine an entire plant of *Lycopodium obscurum* (or of some similar species), noting the trailing stem with its erect leafy branches. How are the leaves arranged on the stem? Are roots present? Note the location and structure of the cones or *strobili*, each made up of numerous *sporophylls*. What is the arrangement of the sporophylls? In what ways do they differ from the foliage leaves? Remove several sporophylls from a strobilus and examine (*m*). On which side of the sporophyll is the sporangium borne? What is its shape? Open a sporangium and prepare a temporary mount of the spores. Examine (*hp*) and note their general character. Are the spores all alike?

Draw a strobilus and a portion of the vegetative shoot. Also draw a single sporophyll with its sporangium. Draw several spores.

Observe a simpler species, such as *Lycopodium lucidulum*, where the sporophylls are scattered along the stem and not organized to form a strobilus. Do the sporophylls occur in groups? Is there as much differentiation between sporophylls and foliage leaves as in the other species studied? Draw a portion of the shoot.

Study (*lp*) a prepared slide showing a cross section of the stem of *Lycopodium*. What is the relative size of the stele and cortex? Is a pith present? Note (*hp*) the presence of thick-walled *xylem* and thin-walled *phloem*. How are these conducting tissues arranged in the stele with reference to each other? Is a cambium present?

Make a diagram of a cross section of the stem.

Exercise 97

SELAGINELLA

Observe (*m*) plants of *Selaginella,* noting the stem and small foliage leaves. Are all the leaves of the same size? What is their arrangement? Terminal strobili are present, each consisting of two kinds of sporophylls: *microsporophylls* and *megasporophylls.* Carefully dissect a mature strobilus and distinguish (*m*) between them. Which kind is borne near the base of the cone? Mount a sporophyll of each kind and examine (*lp*). How do the size and number of the *megaspores* (large spores) in a *megasporangium* compare with the size and number of *microspores* (small spores) in a *microsporangium?* Are the two kinds of sporangia of the same color? Because two kinds of spores are produced, *Selaginella* is said to be *heterosporous.*

Draw a strobilus and a portion of the leafy stem (×5), as well as both kinds of sporophylls with their sporangia. Also draw a single megaspore and a microspore to the same scale.

Exercise 98

EQUISETUM

In the common field horsetail (*Equisetum arvense*), the rhizome gives rise to *fertile shoots* in the early spring and to *sterile shoots* during the rest of the growing season. Both are jointed and longitudinally fluted. Compare them as to color and degree of branching. Are both the nodes and internodes hollow? Examine (*m*) the scale-like leaves. How are they arranged on the stem? Are they united or separate? Where do the branches arise with reference to the leaves? Examine a strobilus borne at the tip of a fertile shoot. The strobilus consists of *sporangiophores,* each bearing a number of sporangia. How are the sporangiophores arranged? Remove several and examine (*m*). What is their shape? Where are the sporangia borne?

Place a few dry spores on a slide, breathe on them gently, and examine them quickly (*lp*). What do you find attached to each spore? Are the spores all alike?

Draw a fertile and a sterile shoot. Also make an enlarged view of a single sporangiophore with its sporangia.

Examine (*lp*) a cross section of the stem of *Equisetum*, noting the central cavity, the ring of large *vallecular canals* in the cortex, and the smaller *carinal canals* which alternate with them. Correlate the position of both sets of canals with the ridges and grooves on the surface of the stem. Where does the green tissue occur? Each carinal canal marks the position of a much reduced *vascular bundle*. In one of these try to distinguish (*hp*) between the xylem and phloem. How are they arranged with reference to the carinal canal? Is a cambium present?

Make a diagram of a cross section of the stem; also draw a single vascular bundle.

Exercise 99

THE FERN SPOROPHYTE

Examine whole fern plants, either living or dried, and note the horizontal underground stem (rhizome) giving rise to roots and to large leaves. Observe the numerous leaflets into which the blade is divided and study (*m*) their venation. On the underside of the leaflets observe (*m*) the *sporangia* arranged in groups called *sori*. Each sorus may be covered with a flap-like membrane, the *indusium*. What is its shape? What is the position of the sori in relation to the veins? Remove some of the sporangia and prepare a temporary mount. Examine (*hp*), noting the stalk, the outer layer of sterile cells, and the inner mass of spores. Note the ring of thick-walled cells, constituting the *annulus*, which extends vertically about two-thirds of the way around the sporangium. Mount several ripe sporangia in a drop of glycerine and examine at once (*lp*). Explain the behavior seen.

Draw a fern leaflet (×3) showing the arrangement of the sori and the character of the indusia, if present. Also draw a single sporangium.

Study living or dried specimens of several other types of ferns, noting (*m*) in each case the exact position and character of the sori. Determine whether the indusium represents an upgrowth of the leaf or is formed by its inrolled margin. Make drawings of three or four species, indicating their distinctive features.

Study a prepared slide showing a cross section of the rhizome of the bracken (*Pteris aquilina*). Note (*lp*) the number and arrangement of the vascular bundles and of the groups of fibers. Examine (*hp*) a single bundle and determine the position of the xylem and the phloem with reference to each other. Is a cambium present?

Make a diagram of the entire stem and a detailed drawing of a single vascular bundle.

Exercise 100

THE FERN GAMETOPHYTE

When a fern spore germinates, it produces a small, green, heart-shaped gametophyte which lies flat upon the ground. Examine one of these (*m* and *lp*), noting on the lower surface the numerous absorptive *rhizoids* and the two kinds of sex organs: the small globular *antheridia*, found among the rhizoids, and the flask-shaped *archegonia*, located near the notch. Observe that the lower portion of each archegonium is embedded in the gametophyte and that only the short, curved neck protrudes. Each archegonium contains a single non-motile egg, while each antheridium produces a number of multiciliate sperms. From the fertilized egg a new sporophyte arises. Examine (*m*) a young sporophyte still attached to the gametophyte.

Draw a fern gametophyte showing the features observed.

SPERMATOPHYTES

Exercise 101

THE PINE SPOROPHYTE

Using any available species of pine, study the arrangement of the needle-like leaves on the stem. How many leaves occur in a bundle? Find the scales at its base. Observe (*m*) the rows of stomata on the leaf; they appear as fine white dots. Study (*lp*) a cross section of a pine leaf, noting the cuticle, epidermis with its sunken stomata, sclerenchyma, mesophyll with several resin ducts, endodermis, and one or two vascular bundles. How is the xylem arranged with reference to the phloem? Examine (*lp*) a cross section of a young pine stem and identify the following tissues: pith, primary xylem, secondary xylem, cambium, secondary phloem, vascular rays, cortex, cork, epidermis with its cuticle (if present). Note the resin ducts in the wood and cortex. How many years old is the stem? What is an annual ring?

Draw a portion of the pine stem with a few leaf clusters attached. Make a diagram of a cross section of a pine leaf and of a young pine stem.

Study both staminate and young ovulate cones (strobili) of any available species of pine. Where are they borne? Do they occur singly or in clusters? Note that they are composed of a number of overlapping scales. Remove several scales (microsporophylls) from a staminate cone and examine (*m*). On which side of the scale are the two *pollen sacs* (microsporangia)? Remove and examine (*hp*) some of the pollen grains, noting the pair of wings. Examine several scales removed from an ovulate cone. Where are the two *ovules* (megasporangia) borne? Obtain a mature ovulate cone and note the woody character of the scales. How are the seeds dispersed? To what structures in a flower do the cone scales of a pine correspond? To what structures in a cone of *Selaginella?*

Draw a staminate and a young ovulate pine cone (×2 or larger). Also draw individual scales removed from each as seen from two different aspects.

Exercise 102

PINE OVULE AND SEED

Study (*lp*) a prepared slide showing a median longitudinal section through a pine ovule. At the apex note the *micropyle*, a passageway leading through the *integument*, or outer covering, to the main body of the ovule. The central portion of the ovule is occupied by the *female gametophyte*. Observe (*hp*) the number, position, and character of the *archegonia*, each of which contains a large egg. Do you find any evidence of the presence of pollen tubes? Obtain a soaked seed of one of the "nut pines," remove the hard *testa*, and dissect out the *embryo* from the surrounding *endosperm*. What is the origin of the testa, embryo, and endosperm? Where is most of the food stored? Examine (*m*) the embryo, noting the *radicle* at the lower end, the *hypocotyl* in the middle, and the whorl of *cotyledons* at the apex. How many cotyledons are present? Where is the stem tip?

Draw a longitudinal section of a pine ovule containing a mature female gametophyte. Also draw an embryo removed from a pine seed.

Exercise 103

ANGIOSPERMS

Since a detailed study of angiosperms has already been made, it will be necessary here only to correlate what you already know about angiosperms with what you have learned about the lower groups. Write a brief account, based on the following questions:

To what structure in gymnosperms does the flower of angiosperms correspond? To what structure in pteridophytes does it correspond? From what structures seen in the pteridophytes and gymnosperms have the stamens and carpels of angiosperms evolved? Exactly how does the female gametophyte of an angiosperm differ from that of a pine? Which is the more primitive and why? In terms of structures seen in the lower plants, explain exactly what the ovary represents and how it has probably evolved.

CHIEF FAMILIES OF FLOWERING PLANTS[1]

Exercise 104

SALICACEAE (WILLOW FAMILY)

The flowers of the willows and poplars are imperfect and borne in catkins of two kinds, these occurring on separate plants. Each of the two kinds of flowers lacks a perianth and occurs in the axil of a bract. Study flowering twigs of willow and distinguish between the staminate and pistillate catkins. Remove several staminate flowers and examine (*m*). How many stamens are borne on the face of the bract? Remove and examine several pistillate flowers, noting the bract and single pistil. Of how many carpels is the pistil composed?

Draw a single catkin of each kind. Also make an enlarged view of a staminate flower and of a pistillate flower.

Exercise 105

RANUNCULACEAE (CROWFOOT FAMILY)

The Crowfoot Family is an ill-defined group combining a number of primitive features. Study flowers of the hepatica, anemone, marsh marigold, buttercup, or of some other form. Does the perianth consist of both a calyx and corolla or only of a calyx composed of petal-like parts? Are the perianth segments constant or fluctuating in number? How many stamens are present? Are the carpels separate or united? What is their position with reference to the perianth? What parts of the flower are spirally arranged and what parts are in whorls? Which of the features displayed by the flower you are studying are regarded as primitive?

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[1] In the case of each flower studied, not only should the suggested drawings be made, but a description should be written according to the outline given on p. 46.

Make drawings of a face and side view of a single flower and of a median section through it. Also draw a stamen and a pistil, somewhat enlarged.

Exercise 106

CRUCIFERAE (MUSTARD FAMILY)

The crucifers constitute a well-defined family whose members are easily recognized. In the form studied, note the four-parted flower with its six stamens. Are all the stamens of equal length? What is their arrangement with reference to the petals? Make a cross section of the ovary and observe (*m*) the "false partition" dividing it into two locules. Does this correspond to the division between the two carpels?

Make a face view of a single flower and a side view of a flower with the perianth removed.

Exercise 107

ROSACEAE (ROSE FAMILY)

The Rose Family is large and rather ill-defined. Select several members for study from among such well-known forms as the apple, hawthorn, strawberry, raspberry, rose, peach, and cherry. These flowers agree in being choripetalous and regular with five sepals, five petals, and many stamens, but differ in the number, position, and degree of union of the carpels. Observe that the numerous stamens are borne on the rim of an expanded receptacle. Is the flower that you are studying perigynous or epigynous? How many carpels are present? Are they separate or united?

Draw a single flower both in face and side view. Also draw a flower cut longitudinally in half.

Exercise 108

LEGUMINOSAE (PEA FAMILY)

All members of the Pea Family have a simple pistil which ripens to form a legume, while most of them have ten stamens and an irregular corolla of a characteristic type. Study flowers of sweet pea, garden pea, lupine, or of some other favorable form and note the differentiation among the petals. The large upper petal is the *standard*, the two lateral petals are the *wings*, while the two lower petals are united to form the *keel*. Where are the stamens and pistil? Count the stamens. Are all of them united by their filaments, or is one free and the others united? Observe carefully (*m*) the form of the pistil.

Draw a face and a side view of a flower. Draw a flower with the petals removed; also draw the separate petals.

Exercise 109

UMBELLIFERAE (PARSLEY FAMILY)

The Umbelliferae constitute one of the highest families of choripetalous dicotyledons. Their small flowers are borne in umbels. Examine (*m*) flowers of caraway, dill, parsnip, or some other member and note that they are choripetalous, regular, and epigynous. What is the number of sepals, petals, stamens, and carpels? Observe (*m*) the structure of the fruit.

Make a diagram of the inflorescence. Make an enlarged drawing of a single flower and of a median section through it.

Exercise 110

ERICACEAE (HEATH FAMILY)

The heaths are among the lowest of the sympetalous dicotyledons. Study any available form, noting the degree to which the petals are united. How does the number of stamens compare with the number of petals? To what are the stamens attached? How do the anthers open to liberate the pollen? Of how many carpels is the pistil composed?

Make a face and a side view of a flower. Also draw a single stamen and a cross section of the ovary.

Exercise 111

LABIATAE (MINT FAMILY)

The mints form a distinct family of easily recognized forms. Study flowers of sage, mint, catnip, or of any other available member, noting the sympetalous, more or less two-lipped corolla. How many petals compose each lip? If four stamens are present, are they of equal length? Some mints have only two stamens. To what are the stamens attached? Of how many carpels is the pistil composed? Cut a cross section through the deeply four-lobed ovary, noting (*m*) the number of locules and the number of ovules in each. Are false partitions present? Explain. Does the species you are studying have square stems and axillary flowers? Is it aromatic?

Make an enlarged drawing of a single flower both in face and side view. Also draw the stamens and pistil.

Exercise 112

SOLANACEAE (NIGHTSHADE FAMILY)

Members of the Nightshade Family have sympetalous flowers which, with few exceptions, are regular. Study flowers of petunia, nightshade, or Jimson weed and note the plaited corolla. Note the number, arrangement, and place of attachment of the stamens. Cut a cross section through the ovary and note (*m*) the two locules and numerous ovules. How many carpels are present and to what extent are they united?

Make a side view of a flower. Also draw the pistil and a cross section of the ovary.

Exercise 113

SCROPHULARIACEAE (FIGWORT FAMILY)

The Figwort Family is characterized by sympetalous, more or less irregular flowers with two, four, or, rarely, five stamens. Obtain flowers of snapdragon, foxglove, or beardtongue. Determine the number and place of attachment of the stamens. Are all of them functional? Cut a cross section through the ovary, noting (*m*) the two locules and many ovules. How many carpels are present and to what extent are they united?

Make a side view of a flower. Also draw the pistil and a cross section of the ovary.

Exercise 114

COMPOSITAE (COMPOSITE FAMILY)

The composites comprise the highest family of dicotyledons. They are characterized by the occurrence of flowers in a head surrounded by an involucre of small bracts. In most composites, the head consists of peripheral *ray flowers* and central *disk flowers.* Dissect a head of the form to be studied and examine (*m*) the individual ray and disk flowers. The expanded portion of the ray flower is composed of five petals united along their lateral edges, while in the disk flower the five petals form a tubular corolla. The cottony or bristle-like structure at the base of the corolla represents the calyx. Observe that the five stamens are united to form a tube, that the pistil is composed of two carpels, and that the ovary is inferior. Identify the floral parts in both ray and disk flowers. Are any of these wanting?

Make a drawing of the head as seen from the front and also from the side. Draw a single ray flower and a single disk flower, both considerably enlarged.

Exercise 115

GRAMINEAE (GRASS FAMILY)

The grasses are monocotyledons which have probably become degenerate. Their general character may be illustrated by flowering plants of oats. Study the gross features of the plant, noting the hollow stem and sheathing leaves. The inflorescence is a panicle and consists of numerous *spikelets*. Each spikelet is enclosed by a pair of leaf-like bracts called *glumes*. Remove these and observe (*m*) the presence of one or two fertile flowers, each enclosed by a bract, called the *lemma*, which bears an *awn*. A single sterile flower will probably also be present in the upper part of the spikelet. Carefully unfold the lemma from a fertile flower and note the *palet*, a smaller bract which stands opposite. The lemma and palet probably represent a reduced calyx. Observe that the fertile flower has three stamens and a pistil with two styles. How are the styles peculiar? Note the presence, just below the ovary, of two minute scales. These are the *lodicules* and are supposed to represent two greatly reduced petals.

Draw a spikelet, a spikelet with both glumes removed and the lemma and palet separated, and a single flower with the outer bracts removed.

Exercise 116

LILIACEAE (LILY FAMILY)

The lilies constitute the most representative family of monocotyledons. The trillium, tulip, adder's-tongue, or other available form may be used to illustrate the family characters. The perianth is composed of two whorls, but the sepals and petals are nearly always alike. How many sepals, petals, stamens, and carpels are present? Is the ovary superior or inferior? Cut a cross section through the ovary and note the number of locules and the place of attachment of the ovules.

Make a drawing of a single flower, a sepal, a petal, a stamen, and the pistil. Make a diagram of a cross section of the ovary.

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